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REPORT

OF THE

CHIEF OF ORDNANCE

TO

THE SECRETARY OF WAR

FOR

THE YEAR 1883.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1884.

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REPORT OF THE CHIEF OF ORDNANCE.

WAR DEPARTMENT, ORDNANCE OFFICE,
Washington, October 1, 1883.

SIR: I have the honor to submit the following report of the principal operations of the Ordnance Department during the fiscal year ended June 30, 1883, with such remarks and recommendations as the interests of this branch of the military service seem to require.

The fiscal resources and expenditures of the Department during the year were as follows, viz:

Amount in the Treasury to the credit of the appropriations on June 30, 1882	$616,341 81
Amount in the Treasury not reported to the credit of the appropriations on June 30, 1882	7,391 69
Amount in Government depositories to the credit of disbursing officers and others on June 30, 1882	216,943 83
Amount of appropriations for the service of the fiscal year ended June 30, 1883	*1,930,087 56
Amount refunded to ordnance appropriations in settlement of accounts during the year ended June 30, 1883	15,010 26
Gross amount received during the fiscal year ended June 30, 1883, from sales to officers; from rents; from collections from troops on account of losses of, or damage to, ordnance stores; from Chicago, Rock Island and Pacific Railroad Company; from powder and projectiles (proceeds of sales); from sales of condemned stores; from testing machine, and from all other sources not before mentioned	130,087 42
Total	2,915,862 57
Amount of expenditures during the fiscal year ended June 30, 1883, including expenses attending sales of condemned stores, powder, and projectiles, &c	*1,808,669 33
Amount deposited in Treasury during the fiscal year ended June 30, 1883, as proceeds of sales of Government property	94,650 06
Amount transferred from ordnance appropriations in settlement of accounts during the fiscal year ended June 30, 1883	112 08
Amount turned into the surplus fund on June 30, 1883	148,948 61
Amount in Government depositories to the credit of disbursing officers and others on June 30, 1883	227,814 45
Amount in the Treasury not reported to the credit of appropriations on June 30, 1883	5,966 57
Amount in the Treasury to the credit of appropriations on June 30, 1883	629,701 47
Total	2,915,862 57

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* Including $7,500 appropriated by act of Congress approved March 11, 1882, for the erection of a monument to the memory of General James A. Garfield.

STATIONS AND DUTIES.

The stations and duties of the officers of the Ordnance Department are as follows: Four at the Ordnance Office; thirty-five at the arsenals, armory, agency, and powder depots; nine on the Ordnance Board and at the foundries; eight at the several military headquarters and ordnance depots; four at the Military Academy; one under the orders of the Secretary of the Interior; one in the Life-Saving Service, under the Secretary of the Treasury; and one on leave of absence, sick. Under the operation of existing laws two officers (Lieutenants Hobbs and Howard) have been transferred to the Department from the line of the Army, after passing a satisfactory examination.

The Ordnance Department provides the armament for our sea coast defenses, and arms and other ordnance stores for the Army, the militia, the Marine Corps, all other executive departments to protect public money and property, and the thirty colleges authorized by law to receive them for instruction. It has not only to provide these ordnance and ordnance stores of the very best quality and most perfect workmanship, to determine on the most effective material for war purposes, after careful study and trial, but to keep up with the important results of the inventive genius and mechanical execution of this progressive age.

A recent inspection of the armory and several of the most important arsenals satisfies me that the varied duties of the Ordnance Department are performed with great skill, economy, and efficiency, and that our ordnance officers are fully equal to any demand upon them requiring the highest professional attainments.

Some very valuable reports and papers by officers of the Department are submitted, most of which have been printed as Ordnance Notes and distributed to the Army. The frequent commendations received by our publications is the best proof of their value and influence, and of the wisdom of continuing the series and giving them a wide circulation.

SMALL-ARMS.

There were manufactured at the National Armory, Springfield, Mass., during the fiscal year ending June 30, 1883, 33,621 arms, including rifles, carbines, and shot-guns. A very large amount of work was also done in repairing, making spare parts, manufacturing swords and sabers, and miscellaneous supplies, and the Armory continues to hold its high reputation for the superior character of its work and products.

MAGAZINE-GUNS.

Three magazine guns were recommended by the Board in its report of September, 1882, consisting of the Lee, the Chaffee-Reece, and the Hotchkiss. By your authority, immediate steps were taken to provide as large a number of each for trial in the field as the appropriation would permit. The Hotchkiss gun is being made by the Winchester Arms Company, where arms on the same system are made for the trade. The Chaffee-Reece gun is now under process of manufacture at the National Armory. There being no private factory with suitable plant, the work could be more economically done by the Department. The Lee gun has not been contracted for, the parties interested laboring under financial difficulties. It is believed, however, that the guns will be forthcoming in time to be sent into the field with the other two early next spring. The trial of these guns, representing the systems of detachable and fixed magazines, will most assuredly be of great value in determining on the most suitable magazine arm for the military service.

SPRINGFIELD SHOT-GUNS.

A sufficient number of these arms have been completed, and the troops west of the Mississippi have been supplied with them—two to a company, with a supply of ammunition. These guns have been most acceptable to the soldier in the field. It is not known that any other army in the world on frontier service is so well supplied with special means of acquiring skill in the handling of arms while providing a variety of food by hunting.

MEDALS—REWARDS FOR TARGET PRACTICE.

The suitably inscribed gold and silver medals to be awarded to the successful marksmen in Army contests, as provided in General Orders 53, of 1882, and to become the absolute property of the winners, have been prepared at the Philadelphia mint. They were received in ample time to send them to the several headquarters in advance of the date of the contests. Medals may now be delivered immediately after the the successful marksmen have been named.

ARMAMENT OF FORTIFICATIONS.

During the last Congress, a select committee of five Senators, of which Senator John A. Logan was chairman, was appointed, "with instructions to take into consideration the subject of heavy ordnance and projectiles," &c.

After as careful a consideration of this very important subject as the time at its disposal would permit, the committee stated in brief the conclusions it had reached as to "the most judicious and economical method of meeting the heavy-ordnance question in the future," and made several recommendations, all of which were subsequently embodied in the act making appropriations for fortifications, &c., approved March 3, 1883, as follows:

> For the armament of sea-coast fortifications, including heavy guns and howitzers for flank defense, carriages, projectiles, fuzes, powder, and implements, their trial and proof, and all necessary expenses incident thereto, including compensation of draughtsmen on gun construction while employed in Ordnance Bureau, and for conversion of 10-inch smooth-bore cannon into rifled guns, making and testing two 12-inch cast-iron rifled breech-loading cannon, in lieu of such of the guns the construction of which has not been commenced, as were provided for by the "act making appropriations for fortifications and other works of defense, and for the armament thereof, for the fiscal year ending June 30, 1881, and for other purposes," approved May 4, 1880, making and testing two breech-loading steel guns, one 8-inch and one 10-inch, making mortars and gun-carriages, mounting 15-inch guns, making and testing two guns banded or wrapped with wire, testing devices for breech-loading guns, testing projectiles, &c., in accordance with the report of the Select Committee of the Senate on the Subject of Heavy Ordnance and Projectiles, $400,000.

Under the specific provisions of this act contracts have been made:

1. For converting fifty 10-inch Rodman smooth-bore guns into 8-inch rifles, by lining with a coiled wrought-iron tube.
2. For making two 12-inch cast-iron breech-loading rifles, one of which is to be lined as far as the trunnions with a steel tube wrapped with wire.
3. For making one 12-inch cast-iron mortar, banded with steel hoops.
4. For making one 10-inch cast-iron breech-loading rifle, wrapped with steel wire, and one 12-inch cast-iron breech-loading rifle, tubed, and banded with steel hoops.
5. For the tubes, hoops, &c., for one 8 and one 10 inch steel rifle.
6. For testing the "devices for breech-loading guns" submitted by H. F. Mann and Col. Theo. Yates.
7. And twenty-five carriages for 15-inch smooth-bore guns have been ordered to be altered, to permit the use of increased powder charges.

In the purely experimental guns in the above list, with one exception, *steel* is used wholly or in part in the construction. Whether or not *gun steel*, in suitable masses and of the requisite quality, could be procured in this country had first to be considered. In order to put our wants fairly and squarely before our steel manufacturers, the following circular letter was freely distributed to more than twenty of the principal steel works in the United States:

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, April 3, 1883.

———————
———————:

GENTLEMEN: I inclose herewith drawings giving the dimensions and weights for certain steel forgings, to wit, the tube, jacket, and trunnion-hoop for an 8-inch breech-loading rifle, and the trunnion-hoop for a 12-inch muzzle-loading rifled mortar, the construction of which is provided for by the act of 1883 for the armament of fortifications, and request that you will inform this office whether you possess the facilities for manufacturing the same, of the qualities specified below.

Open hearth or Siemens-Martin steel is required. The ingots for the tube and jacket should weigh two and one-half times as much as the solid forgings, that the lower and sounder part only of the ingots may be used; and further, the diameter for the tube should be twice, and for the jacket as nearly twice as possible the diameter of the finished forging, in order that the part of the ingots used may be drawn out under the hammer—that for the tube to four times its primitive length, and that for the jacket to not less than two and one-half times its primitive length, more is desirable. When turned to the diameters shown on the drawing, the forgings should be free from spots or soft places on the exterior.

The physical qualities of the forgings, ascertained from tests of rings cut from each end after treatment, should be as follows, viz:

Nature.	Elastic limit.	Resistance at rupture.	Elongation at rupture.
	Tons.	*Tons.*	*Per cent.*
Tube	18	38	18
Jacket	20	40	14
Trunnion-hoops	20	38	7

To obtain the above qualities, using a low steel, special treatment will be requisite, the precise steps of which, as well as the most suitable proportion of carbon, must be ascertained by experiment. The general mode of procedure would be thus: After forging, the tube is annealed and specimens for test taken; if satisfactory, it is then rough bored and turned, and tempered in oil that is kept cool by a current of water, the time of its immersion in the oil being brief; it is then a second time annealed.

The above is the method employed in France and Russia for the treatment of gun steel, and differs, it is believed, from the process followed at the Royal Gun Factory and Sir William Armstrong's works in England, in annealing again after the oil tempering. Krupp dispenses with oil tempering altogether, claiming to attain equally good results by covering the ingots, when withdrawn from the mold, with hot ashes and keeping them so covered for months at a time, allowing the metal to cool very gradually. At the German works of Bochum also, and at Witten, gun steel is not oil tempered, as it is thought the process is attended with too much uncertainty. There, steel projectiles alone are tempered in oil. According to the Russian practice, it is stated, the tubes are allowed to remain in the oil tank only ten or fifteen minutes, and are then replaced in the heating furnace, from which the fire has in the mean time been withdrawn, and allowed to cool slowly.

The following tables, taken from French sources, give some data relative to the effect produced by this mode of treatment.

EFFECT OF TEMPERING AND ANNEALING ON CAST STEEL FOR GUNS.

The following table shows the influence of hammering, tempering, and annealing at different temperatures on cast steel run into ingots.

Treatment of the bars.	Limit of elasticity.	Ultimate strength.	Elongation at rupture.	Remarks.
	Tons.	*Tons.*	*Per ct.*	
Bars cut from the ingot in its natural state	15.7	28.7	6.0	
Bars cut from the ingot and then hammered	34.9	45.0	6.4	
Bar cut from the ingot and then hammered and tempered	27.3	52.5	10.3	Tempered in oil.
Bars cut from the ingot and then annealed at a yellow heat	20.6	35.5	11.9	
Bars annealed at a higher heat than the yellow	18.3	36.5	19.4	
Bars cut from the *annealed* ingot and afterwards tempered	24.7	48.0	7.4	Tempered in oil.
Bars cut from the *annealed* ingot and afterwards tempered and annealed.	22.6	38.0	19.0	Tempered in oil.

The following results were obtained from several specimens of gun steel (Bessemer or Martin) forged and then tempered.

Tensile tests.	Krupp steel for hoops.		Krupp gun steel.			Creusot gun steel.		
	Natural state.	Tempered in oil.	Natural state.	Tempered in water.	Tempered in oil.	Natural state.	Tempered in oil.	Annealed after tempering.
Elastic limit, tons per square inch	16.5	19.0	......	......	......	16.5	24.0	21.0
Elastic elongation, per cent	0.132	0.140	......	......	......	......	......	......
Ultimate strength, tons per square inch	34.8	48.5	41.3	48.5	62.0	35.0	44.5	41.5
Elongation at rupture, per cent	7.4	5.5	21	4.5	1.0	18.7	13.0	16.5

This mode of treatment, by annealing after oil tempering, would seem to give a more suitable metal—one that combines a high elasticity with a considerable ductility—than any other mode of which this Department has information, and it is claimed that steel thus produced is rendered fairly homogeneous.

There will also be required for the two guns in question a number of steel hoops of the following dimensions, viz:

Number of hoops.		Outside diameter, approximate.	Inside diameter, approximate.	Width, approximate.
		Inches.	*Inches.*	*Inches.*
For gun, total 39	11	32.1	26.2	8.2
	18	25.0	20.0	7.4
	10	20.6	15.4	8.5
For mortar, total 14.	6	41.6	35.8	9.0
	8	37.0	29.0	11.0

The physical properties required for the hoops are as follows:

Elastic limit	tons	22
Resistance at rupture	do	42
Elongation at rupture	per cent	9

The hoops would best be obtained by rolling, and the preference is given abroad to horizontal rolling-mills.

In case you possess a tire rolling-mill, the alterations necessary to adapt it to the manufacture of gun hoops should be determined with a view to rolling hoops of 12 inches width, if desired. A width of 7 inches is the least that would be accepted, exclusive of the margin of 1¼ inches from which specimens for test are taken.

The hoops, also, should the tests made for that purpose prove satisfactory and the operation be attended with certainty, would be oil-tempered. This seems to be the practice at present in Europe outside of Germany.

The data given below shows the excellent physical properties of the oil-tempered hoops manufactured at the Creusot Works in France and Sir Joseph Whitworth's works in Manchester, England. The figures were furnished this office directly from those works.

Physical qualities of very large hoops furnished by foreign manufacturers for guns.

Manufacturer.	Elastic limit.	Resistance at rupture.	Elongation at rupture.
	Tons.	*Tons.*	*Per cent.*
Creusot Works cast steel, tempered in oil	20	39	14.0
Whitworth & Co. soft state	19 to 23	32 to 36	24 to 28
Whitworth & Co. tempered in oil	25 to 30	40 to 50	15 to 20
Russian Government Works tempered in oil	23	37	8.0

Sir Joseph expresses his ability to furnish a stronger metal than the above and still retain ample elongation for gun material. Of the admirable quality of his steel there is no question, and his method of compressing the metal in the fluid state, and afterwards of subjecting it again to pressure instead of hammering, should seem to be the very best treatment for securing a sound and homogeneous product. It is stated, but with what authority is not known, that when Whitworth tempers his steel in oil he afterwards anneals it. The tube (oil-tempered) of the 12-inch Whitworth rifle tested at Gavre gave a strength of 47.6 tons per square inch, with an elongation of 20 per cent.

The following table shows the influence of tempering on steel bars with different proportions of carbon.

INFLUENCE OF CARBON.

The results of some experiments made at Terre-Noire, on steel bars 0.8 inch in diameter and 7.9 inches long, are here given.

Amount of carbon.	Condition of the bars.	Elastic limit.	Resistance at rupture.	Elongation.
		Tons.	*Tons.*	*Per cent.*
0.150	Raw state	11.0	23.0	32.5
	Tempered in oil	20.0	29.0	28.0
	Tempered in water	18.0	28.0	19.0
0.490	Raw state	15.0	30.0	24.8
	Tempered in oil	27.0	48.0	12.0
	Tempered in water	30.0	52.0	2.5
0.709	Raw state	18.0	39.0	10.0
	Tempered in oil	47.0	69.0	4.0
	Tempered in water	Broke in	tempering.	
0.875	Raw state	20.0	49.0	8.4
	Tempered in oil	58.0	68.0	1.0
	Tempered in water	Broke in	tempering.	
1.050	Raw state	25.0	56.0	5.2
	Tempered in oil Tempered in water	Broke in	tempering.	

SIR WILLIAM ARMSTRONG'S EXPERIMENTS ON A STEEL CASTING FOR A TRUNNION HOOP (UNHAMMERED).

Amount of carbon.	Condition of the bars.	Elastic limit.	Resistance at rupture.	Elongation.
0.36	Before tempering in oil	16	27.8	7.5
	After tempering in oil	25	37.7	12.5

The Department will also require a steel tube for a 10-inch rifle wound with wire. The diameter of the forged tube will be about 17 inches, and the length 26¼ feet.

It is hoped that all the steel for the experimental guns to be manufactured this summer can be procured from home manufacturers, so that the Department may be able to furnish the next Congress with such information as to the ability of our steel-makers to produce suitable gun forgings as will warrant the request for a liberal appropriation for the production of steel guns; thus we may hope to gradually develop our home facilities until we are in condition to manufacture steel guns of the largest caliber. It is believed the steel can be furnished if, for the present, the steel-makers will co-operate with one another, the works possessing the best furnaces, for instance, casting the ingots, and then arranging with the works possessing the heaviest hammers to do the forging until their own facilities are sufficient for the purpose.

It is the desire of the Department and the intention of the law to depend on home products exclusively, if possible, but if the heavier forgings must now be procured abroad, the lighter ones may still be produced here. Rolled hoops, especially, should be manufactured here with comparatively little delay or trouble.

Should the proposed 12-inch experimental mortar, cast iron, hooped with steel, prove successful, as there is every reason to believe it will, from the good results obtained with like constructions abroad, it is the intention of the Department to make application to Congress for sufficient appropriations to fabricate a considerable number of such pieces. The manufacture of steel hoops is one of the first and simplest steps in the production of gun steel, and has been in successful operation abroad even where the industries were unable to produce the larger and more difficult forging required for gun tubes.

It is urged upon our steel-makers to give this subject their serious consideration. The Department desires to give all possible assistance and encouragement in this matter.

With your reply I should be pleased to have an expression of your views generally upon the subject-matter of this letter.

Very respectfully, your obedient servant,

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

The replies to this letter were, with one or two exceptions, adverse to undertaking such work, arising, I presume, from want of skill and knowledge in the treatment of steel for gun construction, and from the want of the requisite plant to perfect the forgings. The conclusion reached was that the plant or the experience in this country cannot as yet produce the steel forgings, for tube and jacket, for so large a gun as an 8-inch caliber. The tubes and jacket required for the 8 and 10 inch steel guns have therefore been ordered from Sir Joseph Whitworth & Co., England.

The steel hoops required for the banded guns being of comparatively small mass, and readily produced from an ordinary tire mill, their manufacture has been undertaken by the Midvale Steel Company of Philadelphia. Three experimental hoops were ordered from this company for test, in order to ascertain how nearly they could come up to the requirements of the Department's circular letter. Two of these hoops were of the largest size that will be required for the experimental guns, and one was annealed after rolling, while the other was oil-tempered and annealed. The third hoop was hammered and oil-tempered, being of the size required for the smaller hoops of the 8-inch gun, which are not sufficiently large to admit of being rolled in the mill at the Midvale Works.

The results obtained from the mechanical tests of these hoops, both by traction and by hooping tests (see Appendixes 41 and 42), show that they are fully equal in quality to the best hoops of European manufacture.

The mean results obtained in the tests by traction, on specimens 2 and 3 inches between shoulders, are as follows:

Nature.	Elastic limit.	Ultimate strength.	Ultimate elongation.
	Lbs	*Lbs.*	*Per cent.*
Large rolled oil-tempered hoop	54, 666	98, 333	21.0
Large rolled annealed hoop	44, 700	101, 714	18.12
Small hammered oil-tempered hoop	59, 000	97, 200	16.4

The success attained in the fabrication of these hoops reflects credit on the manufacturers, and testifies to their knowledge both of the qualities requisite in gun hoops, and the best methods of manufacture and treatment for producing them.

The above guns being of an experimental character, their dimensions, and therefore their weight, are somewhat greater than is strictly called for from the probable strains to be endured. But in this respect they can be modified after trial should the results warrant it. In the 8-inch steel gun the tubes and jacket are made as light as is consistent with the requisite strength in order to bring these forgings within the limits of our own manufacturing facilities as early as possible. The employment of two rows of hoops with a gun of this caliber gives a more elaborate construction than is desirable, which may hereafter give way to a single row of hoops, as shown on alternate plan, Appendix 39, should the manufacturers be able, after more experience, to produce the thick hoops with the same certainty of success as the lighter ones. As the construction now stands it should be quite applicable to a gun of 10-inch caliber.

As regards the two 12-inch cast-iron rifles, the Department was requested by the South Boston Iron Works, whose representations before the committee were positive and strongly favorable to cast-iron guns, to line one of them with a thin steel tube. This proposition was acceded to, but it was deemed best to strengthen the steel tube by wrapping it with steel wire, as shown on the Department plan, Appendix 39.

Under the provision of the appropriation act to make and test a cast-iron gun banded with steel, it was at first thought best, on account of its greater simplicity, to make a 12-inch gun on the Italian system, but unfavorable reports having been received of the behavior of the Italian 12-inch guns when chambered for charges of 230 pounds, that system was abandoned for the French, and the plan shown in Appendix 39 adopted.

The 10-inch cast-iron wire-wrapped gun has been modified—in consultation with Dr. Woodbridge—from the plan submitted to the committee, by extending the wire wrapping further forward and under the trunnions.

As regards the 12-inch mortar, cast-iron hooped, experiments are already in progress for determining the most suitable rifling and projectiles. Two 10-inch Rodman smooth-bore guns, cut off at the muzzle to give the proper length of bore, and rifled, were provided for these experiments. The results thus far obtained are fair, and encourage the hope that with our service projectiles a good degree of accuracy may be realized from a muzzle-loading rifled mortar.

The tube for the 10-inch steel-wire gun has been ordered, and the question of a suitable quality of wire, and the best method of producing the longitudinal bars, is being practically worked out by the inventor.

Under the provisions of the law to select two breech-loading devices for test, the Mann and Yates were selected. These guns will be obtained by suitably modifying and lining with a steel tube a 10-inch Rodman smooth-bore gun.

Among the recommendations I made to the Logan Committee was the continuing of the conversion of 10-inch smooth-bores into muzzle-loading 8-inch rifles. That recommendation was based on the satisfactory endurance of the 8-inch rifle, and the penetrating power of its shot at 1,000 yards. Appendix 29 gives the report of this trial "with chilled projectiles against armor plates." The target, 12 inches thick, was composed of three 4-inch plates of wrought iron. Each plate was made by welding and rolling seven 1-inch plates to a single plate 4 inches thick. The quality of the iron was excellent, having a tenacity of 45,000 pounds to the square inch. The plates were assembled by twelve bolts with countersunk heads, which passed through a 24-inch oak backing and a 1-inch plate. The results of the trial show that the 8-inch rifle has sufficient power to penetrate wrought-iron armor eight inches thick at 1,000 yards, and this will include that of more than one-half of the armored vessels of the world. For places where the depth of water will only admit vessels of light draught and of comparatively thin armor, and for secondary positions in more important places, this gun will fulfill all the conditions of a good defense.

Appendix 34 gives the report on the proposed alterations of the carriage to adapt it for the 8-inch rifle. The hydraulic buffer, retraction gear, &c., will hereafter be applied to all such carriages.

Another recommendation made to the committee was the utilization of our three hundred 15-inch smooth-bore guns, by supplying the carriages with hydraulic buffers to absorb the recoil and thus enable us to use the heaviest charges. That the 15-inch is a powerful gun will appear from the report of its trial with steel and chilled cast-iron spherical shot against armor plates (see Appendix 36). The armor-plate target, 6 feet by 11 feet in size, was composed of three plates, two 4 inches thick and one 2 inches thick, total thickness 10 inches, backed by two layers of 10-inch oak timbers, and 1-inch skin plate. These were firmly bolted together by cylindrical wrought-iron bars two and one-half inches diameter, countersunk in the 2-inch face-plate, &c. The target was strongly supported by wrought-iron channel-beams and horizontal beams embedded in the sand. With a charge of 130 pounds powder and a 450-pound-shot, the penetrating power was 10 inches of iron at 1,000 yards, showing that with our improved powders the projectile energy of this gun has been largely increased, and renders it not only efficient for secondary purposes, but a very formidable weapon even in our most important harbors.

Appendix 35 gives the report of the alterations in the carriage deemed absolutely necessary to enable this gun to be used with the maximum charges.

GUN FOUNDRY BOARD.

This Board was constituted under the following order:

[General Orders, No. 20.]

HEADQUARTERS OF THE ARMY,
ADJUTANT-GENERAL'S OFFICE,
Washington, April 3, 1883.

By direction of the Secretary of War the following order of the President is published for the information of the Army:

EXECUTIVE MANSION,
Washington, April 2, 1883.

Under the provisions of section one of the "act making appropriations for the naval service for the fiscal year ending June thirtieth, eighteen hundred and eighty-four, and for other purposes," approved March 3, 1883, the following-named officers of the Army and Navy will constitute a Board for the purpose of examining and reporting to Congress which of the navy-yards or arsenals owned by the Government has the best location and is best adapted for the establishment of a Government foundry, or what other method, if any, should be adopted for the manufacture of heavy ordnance adapted to modern warfare, for the use of the Army and Navy of the United States, the cost of all buildings, tools, and implements necessary to be used in the manufacture thereof, including the cost of a steam hammer or apparatus of sufficient size for the manufacture of the heaviest guns:

Commodore *Edward Simpson*, United States Navy.
Capt. *Edmund O. Matthews*, United States Navy.
Col. *Thomas G. Baylor*, Ordnance Department, United States Army.
Lieut. Col. *Henry L. Abbot*, Engineer Corps, United States Army.
Maj. *Samuel S. Elder*, Second Artillery, United States Army.
Lieut. *William H. Jacques*, United States Navy.

CHESTER A. ARTHUR.

By command of General Sherman:

R. C. DRUM,
Adjutant-General.

The Board has visited the principal steel and iron works in this country and is now abroad pursuing its investigations among the great steel works and gun factories of Europe.

It is hoped that it will be able to submit to Congress such a strong and full report, and make such definite recommendations, that Congress will be able to take prompt action towards providing for the country's great want in suitable facilities and plant for the manufacture of heavy ordnance.

STEEL GUNS AND METAL CARRIAGES FOR FIELD SERVICE.

The Midvale Steel Works, Philadelphia, are now manufacturing the steel parts for a breech-loading field gun, caliber 3.2 inches, designed by the Ordnance Board, under instructions from this office. This gun will be completed in time to be tried next spring, and, should it be a success, a supply of such will be procured for the Army.

A few metal carriages have been made at the Watervliet Arsenal, and will be issued to the light batteries for trial. As soon as any defects are found and corrected, a supply will be provided for the service. This carriage embodies two new and important features designed and applied by Lieutenant-Colonel Buffington, Ordnance Department, consisting of a *reinforced axle*, to prevent its bending and breaking under the increased strains and shocks due to largely increased charges, and a *spring brake* to check the severe recoil. These novel features have stood the test of continued firing, and have simplified the problem of field-carriage construction.

MILITIA.

It is difficult to realize the fact that more than half a generation has passed since the close of the war, and yet that simple fact has a vital bearing for weal or woe on the status of the militia and the arms-bearing force of the country. Recruits for the Army must be between sixteen and thirty-five years of age at the time of their enlistment. In the militia every able-bodied male citizen who is of the age of eighteen and under forty-five years shall be enrolled. The war having lasted four years, the million of men in the service at its close must have been between the ages of sixteen and thirty-nine—those at sixteen being raw recruits, those at thirty-nine being hardened veterans of many campaigns—the mean age being twenty-eight in 1865; if to this be added the eighteen years since the war, the mean age of the soldiers mustered out at the end of the war would be forty-six at the present time, an age about the maximum required for the militia. But even those who were sixteen at the end of the war would now be thirty-four, within one year of the maximum limit required for the Army. It thus appears that in another decade the last remnant of that grand army will have passed beyond the limit of active military service. All the field experiences of the greatest war of modern times will then be lost to the future, and the country's dependence will rest solely on a people whose success in war may have to be gained through reverses and disappointments.

The remedy for this state of affairs is simple and plain. Substantial encouragement should be given to the formation of volunteer organizations in every State, district, and city, by liberal appropriations made by Congress to supply the arms, equipments, tents, ammunition, and other ordnance stores. A well-digested system of organization, and a proper recognition of successful efforts in enforcing strict discipline and perfect drill, would go far to keep such organizations in heart and in the confidence of the country.

The act of 23d of April, 1808, makes an annual appropriation of $200,000 "for the purpose of providing arms and equipments for the whole body of the militia." The bill (S. 1596) reported from the Senate Committee on Military Affairs, during the last Congress, is so liberal and important in its provisions that I venture to insert it here in full, in the hope that it may receive the attention it deserves. I strongly recommend the passage of such a law.

The bill is as follows:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That section sixteen hundred and sixty-one of the Revised Statutes be, and the same is hereby, amended and re-enacted so as to read as follows:

SECTION 1. That the sum of six hundred thousand dollars is hereby annually appropriated, to be paid out of any money in the Treasury not otherwise appropriated, for the purpose of providing arms, equipments, ammunition, ordnance stores, and tents for the militia.

SEC. 2. That said appropriation shall be apportioned among the several States and Territories on the books of the Ordnance Department by the Chief of Ordnance of the Army, under the direction of the Secretary of War, according to the number of Representatives or Delegates to which each State and Territory respectively is entitled in the Congress of the United States: *Provided, however*, That each State and Territory shall only be entitled to the benefits of so much of the appropriation apportioned to it as the proportion of the number of the regularly enlisted, organized, and uniformed active militia, as determined by the report of the Secretary of War made on the preceding first Monday in February, bears to the maximum number of active militia for which such State or Territory is entitled to the benefits of this act. And the amount of said appropriation which is thus determined not to be available shall be covered back into the Treasury.

SEC. 3. That in time of peace the number of active militia for which each State and Territory shall be entitled to receive its apportionment of the appropriations made by this act shall not exceed six hundred regularly uniformed commissioned officers and enlisted men for each Representative and Delegate to which such State or Territory is entitled in the Congress of the United States.

SEC. 4. That the purchase or manufacture of ordnance, ordnance stores, and tents for the militia under the provisions of this act shall be made by the Chief of Ordnance of the Army, under the direction of the Secretary of War, and they shall be receipted for and shall remain the property of the United States, and be annually accounted for to the Chief of Ordnance of the Army by the governors of the States and Territories, for which purpose the Chief of Ordnance of the Army, under the direction of the Secretary of War, shall prescribe and supply the necessary blanks, and make such regulations as he may deem necessary to protect the interest of the United States.

SEC. 5. That all arms, equipments, ordnance stores, or tents which may become unserviceable or unsuitable shall be examined by a board of officers of the militia, and its report shall be forwarded by the governor of the State or Territory direct to the Chief of Ordnance of the Army for the action of the Secretary of War, who shall direct what disposition, by sale or otherwise, shall be made of them; and the proceeds of such sale shall be covered into the Treasury of the United States.

SEC. 6. That for all the purposes of this act the District of Columbia shall be accounted and treated as a Territory entitled to one Delegate in Congress.

The following quotations are from the committee's report, which accompanies the bill:

That in addition to the resolution instructing us to consider the propriety of increasing the annual appropriation for the militia, there have been referred to us a large number of petitions from the officers of the militia relative to an increase of the appropriation and other amendments to the existing militia law.

And again:

A simple statement of fact appears to be a sufficient response to the resolution of the Senate. That an appropriation fixed in 1808 to provide for seventeen States, with a population of eight millions, is inadequate to provide for thirty-eight States with a population of fifty millions, needs no argument. The Chief of Ordnance has for many years urged Congress to increase the appropriation; it was considered and favorably reported to the Senate by this committee in the Forty-fifth Congress, and we think it would be difficult to conceive any reasonable argument against it. * * *

It will be perceived that no provision is made as to the mode of apportioning the appropriation between the States, no requirements for accountability for the property furnished, or limitation on the disposition that the States may make of it. The greatest defect of the law, however, is that it does not allow the furnishing of tents and other articles necessary to provide for camps of instruction. To this omission of the law is largely due the disparity between the different States in the strength and efficiency of the militia.

* * * We accordingly report herewith a bill to increase the annual appropriation to $600,000, and making provisions for its apportionment, and for the care, accountability, and disposition of property issued under it. We also provide in the bill that each State shall only receive such proportion of the amount apportioned to it as the actual number of its active militia bears to a fixed maximum, and we believe this provision wisely calculated to foster and encourage the formation of volunteer organizations in those States where but few now exist.

There have been no material changes in the law relative to the organization of the militia since its original enactment in 1792, and it is obvious that many of its provisions are now obsolete and many amendments desirable.

UNITED STATES TESTING MACHINE.

The commanding officer of the Watertown Arsenal has made his report of tests of iron, steel, and other materials for industrial purposes for the last fiscal year. The report will be submitted to you for transmission to Congress at the next session, as required by law.

The law also provides as follows:

> And the Chief of Ordnance shall give attention to such programme of tests as may be submitted by the American Society of Civil Engineers, and the record of such tests shall be furnished said society, to be by them published at their own expense.

As the result of correspondence and interviews, the following programme was received from the Society of Civil Engineers:

AMERICAN SOCIETY OF CIVIL ENGINEERS,
127 EAST TWENTY-THIRD STREET, N. Y.,
December 23, 1882.

General S. V. BENÉT,
Chief of Ordnance, U. S. A., Washington, D. C.:

DEAR SIR: The Board of Direction of the American Society of Civil Engineers has had under careful consideration the subject of the preparation of a programme of tests of structural materials, to be submitted to you in accordance with the provisions of the last army appropriation bill. In this duty the Board, through its president and secretary, has consulted a number of persons interested in the investigation, production, and use of structural materials, and including not only members of this society, but also members of the American Institute of Mining Engineers, and of the American Society of Mechanical Engineers.

In response to a letter on the subject a number of replies have been received, an abstract of which has been compiled, and a copy of which abstract is at your service.

Some delay has occurred in communicating with you. This delay has been occasioned by the illness and death of our late president, Mr. Ashbel Welch, who was chairman of the committee having this particular matter in charge, and who was about to call upon and consult with you when prevented by his last illness.

A number of the gentlemen interested in this subject recently met, and after considering all the suggestions that had been received, brought into practical shape a general programme, which the vice-president of this society informally submitted to you a few days since. In accordance with your suggestion at that time, there is presented to you herewith this programme.

PROGRAMME.

Congress has appropriated the sum of $10,000 for "caring for, preserving, using, and operating the United States Testing Machine at the Watertown Arsenal" for the fiscal year ending June 30, 1883.

In order to produce the largest immediate results with the small amount appropriated, we suggest that the investigation be limited this year to the compression members of structures, and that co-operation be invited from railroad companies, bridge engineers, architects, and manufacturers and users of structural material strained in compression.

For this purpose we suggest that the Ordnance Department of the United States Army should offer to pay the freight on and to test duplicate compression members either from structures which such parties may have in progress of construction or special shapes prepared for this purpose, provided the same be furnished free of further cost.

If the parties will cause to be manufactured one or more duplicate compression parts from each bridge or structure which they may undertake hereafter, or will furnish special shapes, varying in proportions, preferably in series from twenty to sixty diameters, and varying by increments of five diameters; or if they will manufacture special shapes which they desire to have tested; if they will also furnish at least three small or hand specimens of the same material, prepared as indicated in the note below;* if they will place those parts and pieces, free of cost, on board of some transportation line, obtaining the lowest available rate of freight to Watertown Arsenal, and notify the Chief of Ordnance of the particulars of shipment, also furnishing, so far as they can, a statement of the composition of the metal, and its process of manufacture, and a diagram showing the position the member is intended to hold in the structure, and the computed strain it is expected to bear, that then the Ordnance Department will:

1. Pay the freight on the shipment from the initial point to Watertown Arsenal.
2. Test the compression pieces in due course, as well as the hand specimens.
3. Account to the shipper for the value of the scrap, if required, when the same is sold, or return the same to the shipper, if preferred, paying the freight from Watertown.
4. Furnish the shipper an early special report of the results of the tests of all pieces sent by him, giving him an opportunity of sending a second piece to cover any defects that may have occurred.
5. Furnish the American Society of Civil Engineers promptly, for publication and distribution, full copies of all tests and information obtained therefrom.

Respectfully submitted.

W. H. PAINE,
Vice-President American Society Civil Engineers.
JOHN BOGART,
Secretary American Society Civil Engineers.

This programme, with a circular letter from this office, was widely distributed among engineers and manufacturers. In the hope that the appropriation for the present fiscal year would suffice, I agreed to pay the cost of transporting the specimens to be tested; but subsequently I had to withdraw my consent, the money appropriated not justifying the expenditure. Under the programme no specimens have been received for tests, and I am satisfied that no dependence can be, or should be, placed on voluntary contributions in a matter so vital to the material interests of the country. This work is a national affair, and the necessary expense should be borne by the United States. All that should be required of the Society of Civil Engineers is the preparation of a programme for series of tests; the purchase and preparation of material, and the making of the tests to be paid out of moneys appropriated by Congress.

The number of specimens tested on the Watertown Arsenal machine, during the year ending June 30, 1883, was 4,649. Only 539 of this number were for private parties. More than seven-eighths, therefore, of all the tests made were for the Government service. It is fair to believe that this public work will increase from year to year, and that the day is not far distant when the machine will have to be used exclusively on Government work.

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*These three or more small or hand specimens to be of the same material as the compression member furnished; to be rectangular, and to be reduced to one-half of one square inch in area of section; to be of the same thickness as that used in the construction of the member, unless that thickness should exceed one inch, in which case the small specimen is to be reduced to one inch.

It is desired as far as practicable to shape these specimens from pieces of the same section as those composing the member, preserving the surfaces as they come from the rolls, excepting the removal of the outer scale.

The length of these specimens should be two feet.

The capacity of this machine is limited to tests of extension and compression. Additional machines should be provided for the tests of torsional and transverse resistance, and estimates have been submitted.

I have the honor to submit the following papers, heretofore referred to:

Appendix 1.—Statement of principal articles procured by fabrication at the arsenals during the year ended June 30, 1883.

Appendix 2.—Statement of principal articles procured by purchase at the arsenals during the year ended June 30, 1883.

Appendix 3.—Statement of ordnance, ordnance stores, &c., issued to the military establishment, exclusive of the militia, during the year ended June 30, 1883.

Appendix 4.—Apportionment for the fiscal year ended June 30, 1883, of the annual appropriation of $200,000 for arming and equipping the militia, under sections 1661 and 1667, Revised Statutes.

Appendix 5.—Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1882, to June 30, 1883, under section 1667, Revised Statutes.

Appendix 6.—Statement of arms, ammunition, &c., distributed to the Territories and States bordering thereon from July 1, 1882, to June 30, 1883, under the joint resolutions of July 3, 1876, March 3, 1877, and June 7, 1878, and the act of May 16, 1878.

Appendix 7.—Statement of ordnance, ordnance stores, &c., distributed to colleges from July 1, 1882, to June 30, 1883, under section 1225, Revised Statutes.

Appendix 8.—Statement of arms and ammunition issued to the executive departments during the year ended June 30, 1883, under the provisions of the act of March 3, 1879.

Appendix 9.—Report of action taken during the year ended June 30, 1883, under the provisions of the act approved March 3, 1881.

Appendix 10.—Determination of the value of "c" by Didion's formula for computing the elements of the trajectory in air. By Capt. John E. Greer, Ordnance Department.

Appendix 11.—Instructions for use of the Frankford Arsenal hand-tools for reloading cartridges. By Maj. S. C. Lyford, Ordnance Department. (One plate.)

Appendix 12.—Report on rifle target practice in the Army. By Bvt. Brig. Gen. John C. Tidball, U. S. A.

Appendix 13.—Report on swelled and burst small-arm barrels received from the Army. By a board of officers under the direction of Lieut. Col. A. R. Buffington, Ordnance Department.

Appendix 14.—Direct application of power. By Lieut. Col. A. R. Buffington, Ordnance Department. (One plate.)

Appendix 15.—Bartlett's formulas. By Maj. Geo. W. McKee, Ordnance Department.

Appendix 16.—Report on the tertiary history of the Grand Cañon District. By Capt. C. E. Dutton, Ordnance Department.

Appendix 17.—Report on the improved arm-rack for small-arms, manufactured at the Rock Island Arsenal. By Lieut. Col. D. W. Flagler, Ordnance Department. (Three plates.)

Appendix 18.—Report on an improved capstan. By Capt. Henry Metcalfe, Ordnance Department. (One plate.)

Appendix 19.—Report of some improvements introduced at Frankford Arsenal. By Maj. S. C. Lyford, Ordnance Department. (12 plates.)

Appendix 20.—Headless shell extractor for small arms. By Lieut. Col. A. R. Buffington, Ordnance Department.

Appendix 21.—Report on brush material and the manufacture of brushes. By Capt. A. L. Varney, Ordnance Department. (41 plates.)

Appendix 22.—Report of mechanical tests of wrought-iron jackets for 8-inch rifles. By Lieut. Rogers Birnie, jr., Ordnance Department.

Appendix 23.—Report on the fabrication of 8-inch projectiles. By Capt. D. A. Lyle, Lieut. C. W. Whipple, and Lieut. H. D. Borup, Ordnance Department.

Appendix 24.—Description of the United States testing machine at Watertown Arsenal. By Capt. J. Pitman, under the direction of Maj. F. H. Parker, Ordnance Department, commanding. (12 plates.)

REPORTS OF THE ORDNANCE BOARD.

Appendix 25.—Trial of R. J. Gatling's torpedo gun, caliber 1.45 inches. (4 plates.)

Appendix 26.—Trial of a new magazine feed for the Gatling gun, caliber .45 inch, arranged for the bottle-shaped cartridge. (4 plates.)

Appendix 27.—Trial of a Hotchkiss flank-defense revolving cannon, caliber 1.5748 inches (40 millimeters). (11 plates.)

Appendix 28.—Trial of Gatling gun, caliber .45 inch, with new feed magazine, modified. (3 plates.)

Appendix 29.—Trial of 8-inch rifle with chilled projectiles against armor plates. (11 plates.)

Appendix 30.—Comparison of Rodman, Woodbridge, and Crusher gauges. (1 plate.)

Appendix 31.—Design for a steel field gun with the interrupted screw fermeture. (1 plate.)

Appendix 32.—Trial of a new steel field carriage for the 3.2-inch breech-loading rifle. (2 plates.)

Appendix 33.—Trial and test of a 3.2-inch breech-loading rifle and carriage. (2 plates.)

Appendix 34.—Report on converted carriage for 8-inch rifles. (1 plate.)

Appendix 35.—Report of firing a 15-inch smooth-bore gun with increased charges on a modified barbette carriage. (1 plate.)

Appendix 36.—Firing of 15-inch smooth-bore gun with chilled projectiles against armor plates. (4 plates.)

Appendix 37.—Trial of L. A. Merriam's 3-inch rifle. (1 plate.)

Appendix 38.—Report of the principal operations at the Rock Island Arsenal, Illinois, during the fiscal year ended June 30, 1883, Lieut. Col. D. W. Flagler, Ordnance Department, commanding. (9 plates.)

Appendix 39.—Experimental guns being fabricated, under contract. (9 plates.)

Appendix 40.—Showing the stations and duties of the officers of the Ordnance Department.

Appendix 41.—Mechanical tests of specimens taken from steel hoops for cannon. By Lieut. C. W. Whipple, Ordnance Department.

Appendix 42.—Shrinkage tests of steel hoops for cannon. By Lieut. Rogers Birnie, jr., Ordnance Department. (2 plates.)

I have the honor to be, very respectfully, your obedient servant,

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

To the Hon. SECRETARY OF WAR.

APPENDIX 1.

Statement of principal articles procured by fabrication at the arsenals during the fiscal year ended June 30, 1883.

CLASS II.

1	"Baldwin's" mountain gun-carriage saddle.
1	ammunition cart.
1	ammunition wagon.

CLASS III.

1	breech sight for 12-pounder mountain howitzer.
4	breech sights for 8-inch rifles.
32	iron water buckets.
2	drag ropes.
15	elevating arcs and indices for 8-inch rifles.
5	"Bruce's" feed guides for Gatling guns.
6	fuse blocks.
44	gun covers for Gatling guns.
12	gun covers for Hotchkiss mountain guns.
4	gunners' gimlets.
12	gunners' pincers.
52	gunners' sleeves.
116	handspikes, maneuvering.
1	set harness for 2 wheel horses.
1	set harness for ambulance.
75	harness bags.
207	lanyards for friction primers.
4	front sights for 10-pounder Parrott guns.
14	pinch bars.
50	powder funnels.
11	pouches for sights.
12	priming wires for field guns.
20	priming wires for 10-inch guns.
3	priming wires for 15-inch guns.
2	rammers and staves for 3-inch rifled guns.
52	rammers and staves for 8-inch muzzle-loading rifle.
2	rammers and staves for Lyman-Haskell gun.
1	pair shell hooks.
100	securing stakes.
3	scrapers for shells.
2	sponge boxes for Lyman-Haskell gun.
12	sponge covers for 10-pounder Parrott guns.
4	sponge covers for 12-pounder field gun.

2	sponge covers for 8-inch muzzle-loading rifle.
3	sponges and rammers for 6-pounder guns.
10	sponges and rammers for 12-pounder mountain howitzer.
16	sponges and rammers for 12-pounder guns.
18	sponges and rammers for 3-inch rifled guns.
4	sponges and staves for Lyman-Haskell gun.
52	sponges and staves for 8 inch muzzle-loading rifle.
1	sponge and staff for 10-inch gun.
3	tompions for 12-pounder field guns.
1	tompion for 12-pounder mountain howitzer.
1	tompion for 8-inch rifle.
25	vent covers.
1	vent punch.

CLASS V.

3	canisters, filled, for 8-inch guns.
16	wire canisters, filled, for 8-inch rifle.
10	canisters, columnar, for 8-inch rifle.
10	canisters, "Sawyers," filled, for 8-inch rifle.

CLASS VI.

32,000	Springfield rifles, caliber .45.
1,021	Springfield rifles, cadet, caliber .45.
600	Springfield shot guns.
51	officers' light artillery sabers.
100	officers' swords.
4,000	hunting knives.

CLASS VII.

ARTILLERY ACCOUTERMENTS.

31	saber belts.
25	brush and shoe pouches.
120	knapsacks for light batteries.

CAVALRY ACCOUTERMENTS.

368	carbine slings.
150	carbine loops.
3,098	pistol holsters.
25	pistol belts.
824	saber belts.

INFANTRY EQUIPMENTS.

14,950	bayonet scabbard bodies, steel.
15,001	bayonet scabbards, steel, Hoffman attachment.
4,855	blanket bags and straps, with shoulder straps.
11,401	cartridge boxes, pattern 1874.
3,250	cartridge boxes, pattern 1874, woven loops.
40	cartridge belt plates, pattern 1883.
10,501	canteen straps.
10,500	canteens.
2,508	frogs for bayonet scabbards.

12	sliding frogs for non-commissioned officers' swords.
10, 813	gun slings.
6, 500	haversacks.
924	knapsacks and straps, wooden frames.
10, 400	meat cans.
12, 000	tin cups.
345	scabbards for hunting knives.
401	waist belts, grained leather.
5, 060	waist belts and plates, pattern 1874.
2, 500	waist belts, non-commissioned officers.
603	waist belts and plates, without loops.
4	waist belt plates.

APPENDAGES.

882	brush wipers.
11, 044	headless shell extractors.
35, 324	screw drivers.
15, 000	wooden wiping rods.
250	cleaning rods for shot guns.

HORSE EQUIPMENTS.

5, 000	bridles, curb, cavalry.
800	bridles, watering.
50	boots for carbine or rifle and ammunition.
5, 100	hair cinchas.
2, 500	halters and straps.
3, 655	horse brushes.
500	horse covers.
70	horse equipment covers.
4, 993	lariats.
2, 020	picket pins.
1, 210	nose bags.
2, 000	saddles, leather covered.
20	hair saddle-pads, "Sangers".
2	stirrups with guidon sockets.
1, 625	side lines.
2, 100	saddle-bags, leather.
500	saddle-bags, canvas.
3, 109	spur straps.

CLASS VIII.

6, 900	blank cartridges, ½ pound.
1, 350	blank cartridges, 1 pound.
1, 430	blank cartridges, 2 pounds.
21, 541	blank cartridges, 3-inch gun.
8, 650	blank cartridges, 6-pounder field gun.
5, 000	blank cartridges, 12-pounder mountain howitzer.
21, 940	blank cartridges, 12-pounder field guns.
500	blank cartridges, heavy 12-pounder guns.
317, 061	carbine ball cartridges, caliber .45.
1, 008, 528	carbine ball cartridges, caliber .45, reloading, model 1882.
96	carbine ball cartridges, caliber .50.
3, 940, 562	rifle ball cartridges, caliber .45, reloading, model 1881.
58, 864	rifle ball cartridges, caliber .45, 2.4-inch shell.
33, 831	rifle ball cartridges, caliber .50.

255,420	rifle and carbine blank cartridges, caliber .45.
162,725	rifle and carbine blank cartridges, caliber .45, reloading, model 1882.
770	rifle and carbine blank cartridges, caliber .50.
268,308	revolver ball cartridges, caliber 45, reloading, model 1882.
23,866	revolver blank cartridges, caliber .45, reloading, model 1882.
270,532	revolver blank cartridges, caliber .45.
2,000	cartridges for shot guns.
236,275	rifle bullets, caliber .45, lubricated, 405 grains.
1,538,500	rifle bullets, caliber .45, lubricated, 500 grains.
182,000	revolver bullets, caliber .45, lubricated.
100	paper fuses, 16 seconds to the inch.
100	paper fuses, 20 seconds to the inch.
500	wooden fuses for 10-inch guns.
272,140	friction primers.
24	friction tubes for 12.25-inch rifle.
3,320	electric primers.
8	grommet wads for 8-inch gun.

CLASS IX.

36	blocks.
40	quarter blocks.
1	capstan and bars.
1	cradle for heavy guns.
62	gun chocks.
74	roller chocks.
118	wheel chocks.
1	velocity frame.
16	long rollers.
16	short rollers.
12	shifting planks.
8	skids.
1	store truck.
18	trestles for mortars.
17	platforms for mortars.
21	platforms for field and siege guns.
205	Laidley revolving targets.
16	Brinton targets.
7,009,000	pasters for targets.
26,500	paper targets.
15	markers for targets.
46,350	centers for paper targets.
460	streamers for rifle range.
395	signal flags.
29	truck targets.
261	shot marks.
1	wind vane for rifle range.
10	disks.
24	fencing sword blades.

CLASS X.

18	elevating screws for field carriages.
2	shafts for Laidley cavalry forge.
1	wheel for Laidley cavalry forge.
6	linch pins for Laidley cavalry forge.

10	pole prop straps.
16	straps for ammunition chests.
2	caisson straps.
16	ammunition chests.
37	foot-boards and brackets for field carriages.
2	straps for field carriages.
12	wheels for Hotchkiss carriage.
4	artillery collars.
2	artillery collars, Berry's patent.
61	valise straps.
6	wheel traces.
148	girth plates.
2	handspike collars.
19	rammer heads for 3-inch rifled guns.
16	rammer heads for 6-pounder guns.
4	rammer heads for 8-inch rifle guns.
17	sponge heads for 3-inch guns.
10	sponge heads for 6-pounder guns.
6	sponge heads for 12-pounder field howitzer.
1	wire rope sponge.
26	sabots for Lyman-Haskell gun.
93	front sight covers for Springfield carbine.
12	guards for broad swords.
50, 930	spare parts for Springfield rifle, caliber .45.
100	stocks for Hotchkiss navy rifle.
263	stocks for Hotchkiss carbine.
300	triggers.
69	parts for swords.
2, 919	coat straps.
80	canteen loops.
2, 000	belt hooks.
16, 030	artillery buckles.
9	Stuart's sling attachments.
6	canteen corks.
5, 618	clothing-bag straps.
1, 040	canteen corks and chains.
3, 150	canteen covers.
10, 800	haversack straps.
110	leather attachments for hooks.
2, 629	leathers for altering cartridge belts.
1, 000	brass snaps for sabers.
12	canteen cork chains.
5, 000	cavalry curb bits, Shoemaker's.
438	bridle reins.
200	curb-strap loops.
174	Hartman carbine sockets.
100	double loops, artillery.
5, 000	double S hooks.
2, 540	curb straps.
72	curb straps, Shoemaker's.
10, 000	bridle ornaments.
196	girth safes.
692	cincha straps.
80	double-spring snap hooks.
1, 000	Butler & Varney fasteners for side lines.
96	fasteners for side lines.

210	brass rings.
2,692	iron rings.
10,596	D rings.
228	halter bolts.
264	guard-plate ovals.
2,192	halter rings.
132	halter squares.
6,497	halter straps.
7,252	brass staples for rings.
86	girth straps.
6	saddle-bag straps.
24	stirrup straps.
100	cut-off screws for ball-mold slots.
88,646	cartridge bags, empty, various.
31,000	cartridge shells, caliber .45.
6,106,475	cartridge primers.
24,000	cartridge-primer anvils.
21,866	primed shot-gun cartridge shells.
805,000	carbine cartridge wads.
3	gin shoes for field gin.
6	poles for sling carts.
1,308	frames and parts of targets.

MISCELLANEOUS.

1,740	arm chests.
3,660	packing boxes.
100	sheet-iron powder kegs.
1,765	tin cans.
490	cases for shot-gun outfit.

TOOLS.

2	smiths' aprons.
53	armorers' augers.
1	impression block.
2	blades for saddler's gauge.
10	tin buckets.
400	chamois skin sword cases.
320	metal-turning chisels.
5	saddlers' clamps.
350	copper cylinders.
1	steel cartridge.
500	crushers for Lyman-Haskell gun.
3	crowbars.
1,439	assorted drills.
1,600	pressure disks.
42	resizing dies.
984	assorted dies.
36	primer extractors.
1	portable forge.
1,392	assorted files.
199	rotary files.
7	formers for paper shells.
601	funnels for number 20 shells.
335	pounds fulminate of mercury.
16	saddlers' horses.
3	handbarrows.

1	shoeing hammer.
3	loopsticks.
1,376	pounds lubricant.
2,556	primer extractor pins.
500	priming tool pins.
620	priming tools.
25	Michaelis' adjustable powder charges.
914	powder-and-shot charges.
21	reloading punches.
391	assorted punches.
20	resizing punches.
50	primer box openers.
3	dust pans.
179	portable arm racks.
20	shell scrapers.
10	figure stamps.
1	seal stamp.
122,797	pounds alloy for bullets.
50	wiping rods.
5	wrenches.
14	axles and naves for dump cart.
8	wheels for dump cart.
46	assorted bits.
31	iron bolts.
22	heading bumpers.
3	indenting bumpers.
12	trimming bushings.
2	gallons browning mixture.
2	office cases.
220	crimping die caps.
2½	pounds leather polish.
50	boxes for leather blacking ingredients.
1½	pounds scouring material.
50	boxes cleaning materials.
2	fire fenders.
10	button gauges.
1	gauge for length of cartridges.
1	bullet gauge.
65	assorted gauges.
800	gas checks.
211	pounds wheel grease.
334	pounds grease for iron guns.
1	set post harness.
3	ring gauges.
1	lubricant furnace.
1	annealing furnace.
2	pressure gauges.
7	crusher gauges.
1	diameter gauge.
1	pressure gauge housing.
105	gallons lacker.
4	lamps for lighting post.
1,162	armorers' mills.
32	mandrels.
1	cartridge primer varnishing machine.
1	cartridge primer inserting machine, for rifles.

1	cartridge primer inserting machine, for revolvers.
1	punch grinding machine.
2	primer drilling machines.
1	model of 8-inch rifle.
4,368	pounds harness oil.
1,937	pounds paint, various.
4	patterns, various.
1	Woodbridge pressure plug.
5	lamp posts.
6	crusher gauge housing plugs.
1	gravel screen.
70	pounds solder.
6	springs for Le Boulangé chronograph.
14	magazine slippers.
501	stencil outfits, complete.
665	stencil plates.
145	sets stencil plates, Nos. 0 to 9.
364	stencil brushes.
550	stoves for Quartermaster's Department.
231	parts of stoves.
34	window shutters.
1	pound stain.
610½	pounds strawboard, cut.
2	specimen boards, cartridges.
1	specimen board friction primers.
500	stencil paste, tin boxes.
1	tin oil tank.
2	tool bags.
7	tree guards.
150	sets hand tools for reloading cartridges.
3	sets tools for manufacturing reloading tools.
1,483	tools current service.
1	pickling vat.
1⅝	gallons wax mixture.
105	pounds black wax.
1	washing apparatus for cartridge shells.
459	washers for reloading tools.

APPENDIX 2

***Statement** of principal articles procured by purchase at the arsenal during the year ended June 30, 1883.*

CLASS I.

1	Hotchkiss revolving cannon, 40^{mm}.
4	Hotchkiss revolving cannon, 37^{mm}.

CLASS II.

4	carriages and limbers for Hotchkiss revolving cannon, caliber, 1.5-inch.
1	upper carriage and chassis for 12-inch rifle.
1	pintle-bed for 12-inch mortar carriage.
4	traverse circles for 12-inch mortar carriage.
4	Hotchkiss ammunition wagons, complete, for light 37^{mm} revolving cannon.

CLASS III.

4	baskets for mortar implements.
2	cannon scrapers.
720	powder canisters.
6	pointing cords.
4	shell scrapers.
4	sets of implements for Hotchkiss revolving cannon, caliber 1.5-inch.
1	set of accessories for Hotchkiss 40^{mm} revolving cannon for flank defense, French patent.
2	sets of tools for reforming and repriming cartridges for Hotchkiss light 37^{mm} revolving cannon.
1	set artillery harness for 2 wheel horses.
1	set artillery harness for 2 lead horses.

CLASS IV.

36	10-inch rifled mortar shell.
3,400	8-inch Butler cord shot.
36	8-inch Butler shell.
76	8-inch Sawyer canister.
1,000	3-inch Sawyer canister.
550	4.2-inch Butler solid shot.
200	3.20-inch Hotchkiss shot.
751	pounds 8-inch canister shot.
3,200	2-inch chilled balls for canister.
2,350	2¼-inch chilled balls for canister.
2,090	2½-inch chilled balls for canister.
17,000	rounds ammunition for Hotchkiss revolving cannon.

CLASS VI.

1,000	Colt's revolvers, caliber .45.

CLASS VII.

5,000	gray cavalry blankets.
350	cleaning rods for shot guns.
5,437	curry combs.
964	belt hooks,
23	horse brushes.
3	horse covers.
10,367	forks.
10.637	knives.
11,351	spoons.
100	pulley saddle girths.
100	saddle girth fasteners.
3,500	web cartridge carriers.
3,000	woven cartridge loops.
995	rifle cleaners.
500	pistol carriers.
2	collars.

CLASS VIII.

11,500	pounds blasting powder.
10,000	pounds cannon powder.
1,500	pounds experimental powder.
225	pounds giant powder.
3,000	pounds hexagonal powder.
103,500	pounds musket powder.
3	pounds American wood powder.
650,000	rifle ball cartridges, caliber .50.
739,000	rifle ball cartridges, caliber .45.
50	Hotchkiss patent butt-fuse.
47,270	feet safety fuse.
3,000	feet water-proof fuse.
1,400	feet cotton fuse.
35,000	platinum fuses.
50,000	Berdan primers.
29,375	pounds drop-shot.
1,300	paper shells.
100	Draper shells.
8,000	B. G. percussion shot.
3,000	primers.
1,217,000	wads.
41,500	rifle cartridge shells.
415,000	cartridge primers.

CLASS IX.

12	double blocks.
10	single blocks.
2	pulley blocks.
1	gin-sling, field and siege.
1	gin sling, siege and garrison.
3	hydraulic lifting jacks.
6,195	marksman's buttons.
20	rollers.
5	sling chains.
3	sheaves.

CLASS X.

50	8-inch Butler sabots.
425	3.20-inch rifle sabots.
85	bases for canister.
12	bronze hubs for Laidley's cavalry forge.
12	brass fuse plugs.
241	stocks for Hotchkiss rifle.
2,592	halter-bolts.
37	halter chains.
5,040	halter-squares.
1,809	harness-buckles.
72	harness-snaps.
7,944	iron rings.

PARTS OF SCHOFIELD, SMITH & WESSON'S REVOLVER.

12	hammers.
20	hands.
20	hand springs.

PARTS OF COLT'S REVOLVER.

50	back straps.
200	back-strap screws.
25	barrels.
25	cylinders.
6	center pins.
16	center-pin bushings.
7	center-pin catch screws.
119	ejector springs.
56	ejector rods.
12	ejector heads.
50	ejector tubes.
107	ejector tube screws.
100	firing-pins.
100	firing-pin rivets.
15	frames.
50	front sights.
50	guards.
107	guard screws, long.
107	guard screws, short.
2	gates.
103	gate springs.
12	gate catches.
106	gate-catch screws.
24	hammers.
107	hammer screws.
74	hammer cams.
74	hammer rolls.
74	hammer-roll rivets.
12	hands.
107	hand springs.
107	main springs.
107	main spring screws.
112	stocks.

107	stop-bolt screws.
108	sear and stop-bolt springs combined.
107	sear and stop-bolt spring screws.
24	triggers.
107	trigger screws.
1,000	screw-drivers.

PARTS OF GATLING GUN.

1	cocking-ring.
1	lock.

PARTS OF SHOT-GUNS.

2	hammers, right hand.
2	hammers, left hand.
2	sears, right hand.
2	sears, left hand.
243	parts of horse equipments.
32	spokes.
1	wheel for cavalry forge.
2	whips.

PART SECOND: CLOTH, ROPE, THREAD, ETC.

14	yards bed-ticking.
15	yards bunting.
160	yards burlaps.
200	yards canvas.
289½	yards carpeting.
10,683½	yards cotton cloth.
16,751¾	yards cotton duck.
158	yards linen duck.
493¾	yards cotton drilling.
17	square yards enameled cloth.
408½	yards felt cloth.
1	yard oil-cloth.
2	yards wool cloth.
360	yards cotton cord.
193½	pounds hemp cord.
6	pieces hemp cord.
814½	pounds sash cord.
104¾	pieces sash cord.
1	pound cotton batting.
50	pounds cotton rags.
7,292	pounds cotton waste.
163½	yards canton flannel.
468¾	yards flannel.
18	pounds curled hair.
50	yards felt hair.
223	pounds goats' hair.
5,116	pounds horse hair.
199½	yards hollands.
45⅓	yards linoleum.
159½	yards matting.
90½	yards marline.
64	yards "moquette."

4	pounds moss.
10	yards muslin.
47½	pounds oakum.
4	bales oakum.
25,346	pounds rope.
2⅛	pounds tarred rope.
300	feet grass rope.
2½	pounds rope yarn.
½	pound sewing silk.
24	spools sewing silk.
9	skeins silk cord.
20	pounds silk twist.
62	yards tape.
1,930½	pounds thread.
18	spools thread.
12	towels.
37	yards toweling.
243½	pounds tow.
779	pounds twine.
138	balls twine.
40,826½	yards webbing.
4	rolls webbing.
4	gross webbing.
17	window shades.
26	pounds woolen yarn.
8	skeins woolen yarn.

FORAGE.

19,790	pounds barley.
26,392	pounds bran.
78,914	pounds corn.
31	barrels flour.
62	pounds flour.
5	bushels grass-seed.
212	pounds grass-seed.
9,066	pounds ground feed.
34	tons hay.
235,854	pounds hay.
1,880	bushels meal.
22,755	pounds meal.
193,818	pounds oats.
70	pounds rock salt.
15	bushels rye.
104	bushels salt.
60,483	pounds straw.

IRONMONGERY.

28¼	pounds babbitt-metal.
10	bells.
128	pairs blind flaps and screws.
3,971	bolts.
3	bolts and staples.
2,707¾	pounds bolts and nuts.
1,054	pounds branches for pipes.
8	branches for pipes.
159	bushings for pipes.

548	pounds brads.
129	papers brads.
243	pounds burrs.
663½	pounds burrs and rivets.
2,897¼	pounds sheet brass.
265⅜	pounds brass rods.
8	feet brass rods.
17	brass bibs.
288	brass grommets.
2	iron boilers.
3	boiler stands.
91	boiler tubes.
1,510	buckles.
2,064	buttons.
9	caps for pipes.
10	brass castings.
3,895½	pounds brass castings.
101	iron castings.
70,845½	pounds iron castings.
334	wrought-iron beams.
1,323,067	pounds wrought-iron beams.
775½	pounds steel castings.
18	cast-iron plates for columns.
1,684	pounds cast-iron plates for columns.
18	cast-iron caps for columns.
1,376	pounds cast-iron caps for columns.
18	cast-iron plinth-blocks.
1,960	pounds cast-iron plinth-blocks.
64	cast-iron lintels for doors and windows.
24,107	pounds cast-iron lintels.
29	sets casters.
149	feet iron chain.
2,261¼	pounds iron chain.
296	assorted cocks.
462 9/16	pounds bar copper.
251,105½	pounds cartridge annealed copper.
27,177	pounds sheet copper.
108	couplings for pipes.
74	wrought-iron columns.
91,219	pounds wrought-iron columns.
40	cast-iron columns.
20,827	pounds cast-iron columns.
6	wrought-iron cylinder transoms.
4	door catches.
74	door-fixtures.
30	door-springs.
576	ears for cans and buckets.
996	elbows for pipes.
13	ells for pipes.
50	pounds escutcheon pins.
18	iron extension pieces.
92,048	eyelets.
120	fixtures for bath-tubs.
389½	feet gas pipe.
6	gas burners.
2	gas brackets.

480	gas fixtures and fittings.
6	gas meters.
2	sets grate bars.
1	paper glazier's points.
403⅛	pennyweights gold.
42	hinge-hasps.
1,366½	pairs hinges.
4.460	assorted hooks.
3	hose-bands.
7	hose-couplings.
1	hose-nozzle.
10,964	horseshoes.
460	pounds horseshoe nails.
3	hasps and staples.
2	hydrants.
72	pounds angle iron.
116,315½	pounds bar iron.
5,336	pounds boiler iron.
636	pounds iron forgings.
4,142¼	pounds galvanized iron.
276	pounds hoop iron.
148,610	pounds pig iron.
42	tons pig iron.
111,907	pounds wrought iron.
7,986½	pounds sheet iron.
6	sheets sheet iron.
2	iron connections.
1	iron pedestal.
203	assorted knobs.
102	keys and blanks.
7,651¼	pounds lead pipe.
339	feet lead pipe.
25	pounds pig lead.
6,201	pounds sheet lead.
20	latines.
248	feet lightning rod.
744	assorted locks.
6	lock-nuts for pipes.
24	log screws.
1	pound mica.
81	pieces mica.
70	gross saddler's nails.
50,796¼	pounds assorted nals.
73	papers assorted nails.
134	nipples for pipes.
362	assorted nuts.
8,157¼	pounds assorted nuts.
4	offsets for pipes
6	iron pans.
1	copper pan.
71	pounds brass pipe.
9⅓	feet brass pipe.
22	pounds pipe fittings.
71	pipe fittings.
3	iron pipes.
17,162¼	pounds iron pipe.

293	pin radiators.
204	plugs for pipes.
5	pumps.
2	piston rods.
108	pulleys.
44,000	rivets.
1,665¼	pounds rivets.
24	box rollers.
112	feet iron rope.
1	endless wire rope.
6	reducers for pipes.
480	yards safety chain.
4,100$\frac{5}{12}$	gross assorted screws.
1,128	can screws.
4⅛	gross screw-eyes.
254	gross screw pins.
126	pounds sash weights.
12	sash pulleys.
164	shutter bars and screws.
50⅙	feet shafting.
1	shafting.
121½	pennyweights of silver.
29	iron sinks.
25	feet smoke-stack.
325$\frac{9}{16}$	pounds solder.
304	pounds stove castings.
28	S traps.
1,361	pounds steel axles.
1,490	pounds steel axle-plates.
20,654	pounds cast-steel.
102	pounds steel forgings.
584,402	pounds gun-steel.
6,624	pounds machinery-steel.
10,656	pounds steel plates.
20	steel plates.
8,237½	pounds sheet steel.
50	pounds spring steel.
23	pounds staples.
110⅜	pounds spelter.
2	wagon springs.
6,150	pounds spikes.
1,000	brass tacks.
91	pounds copper tacks.
1	paper copper tacks.
68,000	copper tacks.
1,170,500	iron tacks.
419	pounds iron tacks.
44	pairs lead tacks.
448	tees for pipes.
149	boxes sheet tin.
2,145	sheets tin.
11,822	pounds block tin.
885	pounds tin foil.
16	feet brass tubing.
204	pounds brass tubing.
77¼	pounds copper tubing.

1	tuyère iron.
44	urinals and fixtures.
282	unions for pipes.
282	valves.
4	iron wash-vats.
1,200	iron washers.
1,195	pounds iron washers.
37	iron wheels.
152	window fixtures.
2,608	pounds annealed wire.
3,933⅝	pounds brass wire.
2	yards wire cloth.
3,071	square feet wire cloth.
20	square yards wire cloth.
12,184¼	pounds copper wire.
5	feet copper wire.
178½	pounds covered wire.
579½	pounds galvanized wire.
3,388	feet galvanized wire.
6,503½	pounds iron wire.
256	pounds iron-screw wire.
828	pounds steel wire.
16	pieces steel wire.
244¾	feet wire netting.
350$\frac{2}{15}$	feet platinum wire.
761	feet wire rope.
25	wire stretchers.
1	worm and wheel.
1,137¾	pounds sheet zinc.
159	sheets zinc.
202	pounds slab zinc.
7	water closets.
11	water-closet fixtures.
4,617	pounds wrought-iron plates.

LEATHER, ETC.

16	sides alum-tanned leather.
25,222½	square feet bag leather.
6,637½	square feet bellows leather.
3	sides belting leather.
10,895¼	feet belting leather.
2,569	sides bridle leather.
155	pounds buff leather.
118,432¾	square feet collar leather.
31,263½	pounds harness leather.
6	sides harness leather.
11,337	pounds harness-backs.
156¼	pounds lacing leather.
12	sides lacing leather.
2,800	feet lacing leather.
2	skins morocco.
275½	pounds sole leather.
8,334⅜	square feet russet leather.
1	side sole leather.
45	sides special leather.

128¼	pounds walrus leather.
3¼	square feet enameled leather.
30	pounds black wax.
4,175	balls black wax.
2,846½	pounds bristles.
85	feet rubber belting.
2	sheep-skins.

LUMBER.

34	battens.
6,256	feet battens.
1,123,997½	feet boards.
15,777	feet joists.
38,500	laths.
913,226 4/6	feet plank.
710	posts and rails.
330	feet posts and rails.
157,976	feet scantling.
188,750	shingles.
155,306½	feet timber.

BUILDING MATERIAL, ETC.

131⅛	pounds asbestos packing.
18¼	pounds asbestos paper.
24	asbestos washers.
773	balusters.
28	brackets.
1,994,858	bricks.
1	chimney-top.
157	casks cement.
458 48/100	barrels cement.
404	pounds cement.
125	feet cement pipe.
20	loads puddling clay.
4	columns.
48	doors.
170	drain pipes.
4,488	feet drain pipes.
135	feet drain tiles.
4	earthen elbows.
20	feet earthen pipe.
75	barrels fire clay and fire sand.
17	bushels fire clay and fire sand.
45	boxes glass.
704	feet glass.
3,585⅔	square feet glass.
6,904	lights, glass.
362	feet glazed-ware pipe.
11	granite steps and caps.
6	granite door sills.
464	loads gravel.
332	pounds plastering-hair.
46	bushels plastering-hair.
68	feet hand-rails.
2,889 18/100	barrels lime.
851¾	bushels lime.

4	mantles and grates.
25	rolls tarred paper.
605	pounds tarred paper.
74	rolls wall paper.
289	yards bordering paper.
641¼	loads paving blocks.
8,250	paving blocks.
40	barrels plaster of Paris.
50	pounds plaster of Paris.
338½	tons sand.
5	loads sand.
1,673⅒	barrels of sand.
847	bushels sand.
1,719¾	yards sand.
7	moldings, &c.
12,302	feet moldings, &c.
71	feet tin water-spout.
1	tin water-spout.
15½	squares slate.
76	feet slate.
19	loads stone.
$6,580\frac{58}{100}$	cubic yards stone.
4,825¼	feet stone.
$403\frac{22}{100}$	cubic feet artificial stone.
99	sand-stone window sills.
$24,865\frac{86}{100}$	square feet stone flagging.
16	terra-cotta bends and branches.
7	terra-cotta chimney-tops.
7	terra-cotta elbows.
4	terra-cotta pipes.
276	feet terra-cotta pipe.
30	yards terra-cotta pipe.
916	feet weather-strips.
16	sets window blinds.
2	pairs window blinds.
171	window frames.
139	window sash.
24	sets window shutters.
34	window shutters.
199⅒	feet lintels.
2	lintels.
3	barrels kaolin.
2	newells and caps.
$314\frac{11}{16}$	cubic feet rocks.
245⅞	loads rocks.
15	tiles.
4	transoms.
66	square rods sodding.

HEATING, LIGHTING, ETC.

28	argand burners.
6	argand chimneys.
6	argand shades and rings.
400	fire-bricks.
24	sets fire-bricks.

39	bath-bricks.
5	bath-tubs.
1,044	brooms.
91	dust brushes.
761	assorted brushes.
16	china bowls.
81	pounds candles.
10	feet card-clothing.
299	square feet card-clothing.
198	barrels charcoal.
28,226$\frac{4}{10}$	bushels charcoal.
366	pounds charcoal facings.
476	chamois skins.
1	chandelier.
6,073,256	pounds bituminous coal.
3,832,062	pounds anthracite coal.
324	bushels coke.
279,940	pounds coke.
11	pounds crocus.
5	reams crocus and emery cloth.
665¼	quires crocus and emery cloth.
928	pounds corundum.
13	corundum wheels.
7½	carats diamond powder.
7	door mats.
9	dust pans.
211	pounds dubbing, for leather.
4,045	pounds emery.
7½	reams emery paper.
4	quires emery paper.
250	emery wheels.
23	fire grates.
844¾	cords fire wood.
32	fixtures for gas ovens.
14	gas brackets and globes.
9,990½	gallons gasoline.
200	pounds broken glass.
36	glass globes.
63	lanterns.
24	lantern-globes and chimneys.
1	lamp.
24	lamp-burners.
199	lamp-chimneys.
6	lamp-founts.
8	lamp-fixtures.
15	lamp-shades.
386	lamp-wicks.
27¾	pounds lamp-wick.
2	balls lamp-wick.
6	boxes leather blacking.
309	quarts leather blacking.
19½	gross matches.
1,343	pounds machine facings.
7,102	pounds mineral wool.
8	mops and handles.
902	gallons naphtha.

90	gallons astral oil.
504	gallons kerosene oil.
1	gallon polishing oil.
3,140½	gallons sperm oil.
1	oven.
52	gallons paraffine.
50¼	pounds paraffine.
6	basins, pitchers, &c.
1	porcelain sink.
70½	pounds pumice-stone.
29	registers.
142	pounds rotten-stone.
1	barrel rosin.
591	pounds rosin.
47	reams sand-paper.
196½	quires sand-paper.
1	box sapolio.
28¾	barrels soap.
4,700¼	pounds soap.
18	cakes soap.
28	gallons soft soap.
6⅞	pounds carbolic soap.
81½	pounds sponge.
22	stoves.
1	stove lining.
12	stove utensils.
32	papers stove polish.
230	feet stove-pipe.
25	pieces stove-pipe.
110	stove-pipe elbows.
168	barrels sea-coal facings.
6	furnace tiles.
2	tile hearths and facings.
83	papers tripoli.
2	globe ventilators.
1	can rubber cement.
3	gallons water-proof polish.
3	pounds sheep's wool sponge.
3	ounces watch-oil.
12	bottles clock-oil.

MATERIALS FOR OFFICE USE.

12	waste-baskets.
21,072	assorted blanks.
90	memorandum blocks.
9	blotting pads.
12	blotters.
30	blank books.
38	books of reference.
2	book-cases.
294	oil-boards.
50	pounds binders' boards.
7	copy brushes.
4	pans burnt sienna.
1	pound bronze gold.
23,500	assorted cards.

4	pans carmine.
19	chairs.
2	chair cushions.
3	clocks.
3	watch clocks.
16	composition rollers.
14	pounds composition for printers.
2	boxes crayons.
1	gross crayons.
2	bottles Chinese white.
2,000	dials for watch clock.
7	drawing pens.
8	desk-pads.
27	drawing instruments.
48	electrotypes.
98,450	envelopes.
9	pounds rubber erasers.
42	pieces rubber eraser.
29	steel erasers.
13	boxes eyelets.
182	file boxes.
2	invoice files.
5	newspaper files.
9	sticks India ink.
4	inking pads.
90	pieces India-rubber.
1¼	quarts blue ink.
164	quarts black ink.
15	bottles drawing ink.
64	ink erasers.
7	bottles héktograph ink.
3	quarts purple ink.
557	pounds printing ink.
120	bottles red ink.
24	bottles scarlet ink.
26	inkstands.
3,000	assorted printed labels.
60	leads for pencils.
14	quarts mucilage.
48	bottles mucilage.
12	mucilage brushes.
20	mucilage stands.
30	pieces compound mucilage.
25	protecting-rollers for drawings.
2	bottles pounce.
2	pounce-boxes.
24	pencil-pads.
25	sheets agate paper.
50$\frac{4}{20}$	reams blotting paper.
734	sheets blotting paper.
25	sheets belgian paper.
422	sheets paper for blotter-bath.
8	paper cutters.
110¼	pounds drawing paper.
$\frac{13}{15}$	rolls drawing paper.
234	sheets drawing paper.
259	square yards drawing paper.

10	quires demy paper.
33⅞	pounds demy paper.
49	sheets envelope paper.
8	quires envelope paper.
10	boxes paper fasteners.
1, 500	paper fasteners.
2	paper folders.
1	quire ledger paper.
2, 000	sheets ruled paper.
$\frac{11}{12}$	reams printing paper.
50	sheets record paper.
100	reams shoe paper.
1	quire tracing paper.
20	yards solar-printing paper.
142¼	reams writing paper.
1	quire writing paper.
24	paper weights.
2¼	reams wrapping paper.
931	pounds wrapping paper.
3, 440	lead pencils.
105	gross steel pens.
962	quill pens.
324	pen holders.
1	pen rack.
10	boxes pins.
5	pounds pins.
4	pans Prussian blue.
140	yards printer's furniture.
4	rolls ribbon.
4	rulers.
159½	gross rubber bands.
266	pounds roller composition.
11	boxes assorted seals.
10, 000	assorted seals.
367	pounds sealing wax.
1	pair shears.
12	Sisson's binders.
3, 000	shipping tags.
15	spittoons.
71	rubber stamps.
110	sheets stencil boards.
6	sponges for cup.
1	sponge cup.
1, 000	order slips.
4	spools tape.
5, 234	yards tape.
1	tape measure.
87	thumb-tacks.
51	yards tracing cloth.
7	rolls tracing cloth.
92	pounds type.
3	rubber type.
1	writing machine.
3	water coolers.
1, 000	wire staples.
12	telephone cords.
5	telephone batteries.

LABORATORY STORES.

2	bulbs for acid pump.
7	bath-tubs.
41	bottles.
1	specific-gravity bottle.
3	porcelain bowls.
10	carboys.
6	carbon batteries.
22	carbon cells.
20	carbon clamps.
20	carbon connections.
32	carbon porous cups.
20	carbon zincs.
60	crucibles.
20	carbons.
5, 324	corks.
1	cylinder and cover for annealing furnace.
2	demijohns.
12	electric buttons.
4	glass funnels.
20	glass gauges.
10	glass jars.
48	glass insulators.
24	glass plates.
16	glass tubes.
96	insulators and brackets.
2	lenses.
3	Mason's hygrometers.
1	oil hydrometer.
2	magnifying glasses.
2	marble slabs.
3	pieces for electric battery.
51	retorts.
26	stone jars.
7	thermometers.
150	pounds zinc batteries.
6	zincs for batteries.
20	zinc connections.
40	gallons carbolic acid.
14	ounces carbolic acid.
2	pounds crystallized carbolic acid.
11¾	pounds hydrochloric acid.
¾	gallon muriatic acid.
757½	pounds muriatic acid.
1	gallon nitric acid.
4, 622	pounds nitric acid.
1	pound oxalic acid.
2	gallons sulphuric acid.
21, 501	pounds sulphuric acid.
2	pounds assafœtida.
854	gallons alcohol.
7	pounds arnica flowers.
2	gallons tincture of arnica.
4	pounds tincture of arnica.
46	pounds alum.

2	pounds aloes.
50	pounds ammoniated copper.
166	pounds aqua ammonia.
6	bottles healing balsam.
22	pounds bichromate of potash.
110, 161	pounds bone.
212	pounds borax.
100½	pounds camphor.
10	pounds carbonate of iron.
1	pound chlorate calcium.
2	pounds condition powders.
14½	pounds corrosive sublimate.
584½	pounds sulphate of copper.
5	pounds citrate of iron and ammonia.
7	gallons electropion fluid.
581	pounds electropion fluid.
8	pounds Epsom salts.
5	bottles extract of ox-galls.
3	ounces sulphuric ether.
138	pounds flax-seed.
45	grains gold chloride.
532	pounds gum arabic.
525	pounds gum dextrine.
40	pounds gum tragacanth.
6	bottles horse medicine.
1	pound tincture of iodine.
3	ounces tincture of iodine.
1	bottle proto-iodide of mercury.
200	pounds acetate of lead.
12	pounds concentrated lye.
37	cans concentrated lye.
385½	pounds mercury.
2	pounds muriate of iron.
146¼	pounds spirits of nitre.
25	ounces nitrate of silver.
20	pounds nickel salts.
3, 025	pounds potash.
448	pounds chlorate of potash.
1	pound nitrate of potash.
15	pounds cyanide of potash.
14	pounds prussiate of potash.
40	pounds proto-sulphate of iron.
4	boxes rat-poison.
58¼	pounds sal-ammoniac.
8, 148	pounds sal-soda.
2, 811	gallons silicate of soda.
150	pounds soda-ash.
710	pounds sulphur.
129	pounds sulphate of iron.
101	pounds sulphate of zinc.
100	pounds nitrate of strontia.
115¾	pounds beeswax.
169½	pounds chalk.
200	pounds powdered charcoal.
½	ounce oil of cloves.
1¾	pounds gelatine.

2½	pounds powdered ginger.
110	pounds powdered glass.
1	gallon glue.
3, 536	pounds glue.
517	pounds glycerine.
42	gallons isinglass.
2	pounds isinglass.
42	pieces isinglass.
½	pound Irish moss.
5	pounds lard.
2	ounces laudanum.
9	bottles liniment.
4	pounds liniment.
1½	gallons molasses.
6	reams black paper.
400	pounds carbolized paper.
3	quires fuse paper.
50	sheets ferro-prussiate paper.
8	rolls ferro-prussiate paper.
48	sheets litmus paper
13	reams manila paper.
19, 123	pounds manila paper.
768	pounds petroleum paper.
21	pounds pepper.
½	gallon Pond's extract.
4	barrels pitch.
2	bottles royal gilding.
39, 600	pounds straw boards.
2, 716	pounds tallow.
42	pounds bayberry tallow.
46	gallons tar.
20	pounds tobacco.
40	gallons whisky.

PAINTS, OILS, ETC.

2	barrels asphalt.
965	pounds asphalt.
155	gallons benzine.
54	pounds chrome green.
105	pounds chrome yellow.
10	gallons chrome yellow.
19	barrels coal-tar.
403	gallons coal-tar.
289	pounds drop black.
140½	gallons Japan drier.
26½	gallons patent drier.
53	pounds patent drier.
20	pounds hardwood filler.
37	pounds Hampden green.
51	pounds ivory black.
42½	pounds india-red.
4	papers kalsomine.
939	pounds lampblack.
239	pounds black lead
100	pounds dry lead.

1,655	pounds red lead.
35,386½	pounds white lead.
330	pounds litharge.
23	pounds extract of logwood.
2	pounds nut-galls.
10½	gallons castor oil.
209	gallons coal oil.
281½	gallons cod-liver oil.
84¾	gallons cosmoline.
149½	gallons cylinder oil.
1	gallon Downer's oil.
256	gallons elaine oil.
852¼	gallons boiled linseed oil.
2,178$\frac{7}{10}$	gallons raw linseed oil.
3,086$\frac{8}{10}$	gallons lard oil.
466½	gallons machine oil.
196	gallons mineral oil.
88	gallons natural oil.
411¾	gallons neat's-foot oil.
1	bottle olive oil.
60½	gallons valvoline oil.
20	gallons wool oil.
445	pounds oline lubricating compound.
660	pounds black paint.
375	gallons green paint.
10	pounds paint, graining color.
7,529	pounds metallic paint.
1,050	pounds olive paint.
338	pounds assorted paint.
8	gallons assorted paint.
100	pounds Paris white.
25	pounds Paris green.
3,259	gallons petroleum.
14	pounds Prussian blue.
2	quarts prepared tar.
433	pounds putty.
18	pounds plumbago.
10½	pounds rouge.
947½	pounds shellac.
10½	gallons shellac.
2	bottles sienna.
59	pounds burnt sienna.
33	pounds raw sienna.
40	pounds stone yellow.
1$\frac{22}{150}$	barrels stone yellow.
4	pounds turpentine.
1,765	gallons spirits turpentine.
28½	pounds Venice turpentine.
333	pounds burnt umber.
37	pounds raw umber.
41	pounds ultramarine blue.
2	bottles Vandyke brown.
26½	gallons coach varnish.
138½	gallons copal varnish.
6	gallons furniture varnish.
265	gallons Japan varnish.

300	pounds roofing varnish.
569	pounds Venetian red.
112½	pounds vermilion.
3	gallons vinegar.
7,232½	pounds whiting.
2,046	pounds gilder's whiting.
3,580	pounds yellow ochre.
370	pounds zinc.

MISCELLANEOUS ARTICLES.

4	horse blankets.
2,204	packing boxes.
3,798	tin boxes.
50	paper bags.
1	mail-bag.
19	baskets.
49	water buckets.
426	barrels.
72	cups.
500	powder canisters.
321	tin cans.
2	zinc cans.
1	fur cap.
2	chair seats.
1	tin dish.
72	finger-cots.
12	flower-pots.
6	glass tumblers.
1	pair fur gauntlets.
4	pieces gutta-percha.
41	pounds gutta-percha.
10	pounds belt grease.
931	pounds wheel grease.
43	boxes wheel grease.
17	hoppers for closets.
2	hogsheads.
4	sets post harness.
190	parts of harness.
10	horses and mules.
12	iron hoops.
2,700	wooden hoops.
6,952	feet hose.
9,583	pounds ice.
2,420¼	pounds Japan wax.
1	keg.
12	pairs magazine slippers.
1	mirror.
14	oars.
4	oar staves.
1	buffalo overcoat.
2,000	pounds phosphate manure.
5	pounds black-lead packing.
10⅛	pounds flax packing.
282⅛	pounds rubber packing.
1	square foot rubber packing.
79¾	pounds steam packing.
20	pounds hemp packing.

25	basins, pitchers, &c.
3	butter pots.
5	pounds shoe pegs.
1	quart shoe pegs.
1	pump-handle.
11	reflectors.
1	rubber apron.
3	rubber coats.
14	rubber corks.
6	pairs rubber boots and shoes.
11	pairs rubber gloves.
4	sets rubber letters and figures.
26¾	pounds rubber pads.
1	set rubber packing rings.
12	rubber rings.
27¾	pounds sheet rubber.
2,189½	feet rubber tubing.
1	font rubber type.
1	skiff.
1	sand scow.
18	barrels saw-dust.
2	cords saw-dust.
1	set steel runners.
1	sleigh.
206	railroad and street-car tickets.
654	ornamental trees and plants.
1	watering pot.
5	wagon whips.
1	wagon.
161½	parts of wagon.
1	washstand.
1	gallon wood preservative.
1	ventilator.
1	wood-cut.

MACHINES, ETC.

1	anemometer.
1	arbor for 8-inch canister.
1	alcohol pump.
1	15 horse-power boiler.
1	blasting machine.
3	boring machines.
1	cultivator.
1	cistern pump.
1	connecting-rod for steam engine.
1	die-sinking machine.
1	electric machine.
1	fan blower.
1	fire-alarm signal box.
7	force pumps.
1	gas works, complete.
10	gear wheels.
1	grinding machine.
1	galvanometer.
1	gear.
5	gear cutters.
1	80 horse-power hammer.

1	drop hammer.
4	lawn mowers.
290	parts of mowing machines.
1	part of sewing machine.
2	lawn sprinklers.
4	profiling machines.
1	scroll water wheel.
2	steam traps for boilers.
1	soldering apparatus.
5	milling machines.
1	steam-heating apparatus.
1	wrought-iron shoe.
1	telegraph register.
1	water elevator.
1	pendulum pump.
1	wood pump.
1	Waymouth lathe with gauge.
2	centrifugal oil extractors.
1	rotary wire-straightening machine.
2	alidades.
2	arcs.
1	drilling machine.
1	planing machine.
22	parts of machines.
1	sewing machine.
2	iron-hoisting troughs.
1	gas holder.
2	gas drip boxes.
1	copper steam pipe.
1	wrought-iron heater.
1	fire extinguisher.
1	adjustable power press.
1	double punch and shear.

INSPECTING INSTRUMENTS.

5	inspecting instruments for 8-inch projectiles for muzzle-loading rifle.
6	telemeter Boulangé.

TOOLS.

31	augers.
152	awls.
7	axes.
1	bevel.
15	bench screws.
2	Smith's bellows.
47	bits.
69	braces and bits.
1,849	assorted brushes.
1	scratch brush.
1	blow-pipe.
4	baskets.
36	chalk-lines.
14	pounds chalk-lines.
18	chisels.
2	sets chisels.
1	chuck.
4	lathe chucks.

20	clamps.
24	coal-hods.
9	graining combs.
9	pairs compasses.
3	clamp-dogs.
39	assorted carpenters' tools.
3	cold chisels.
1	comb stork.
14	dies.
1	die and stock.
285	drills.
901	maple drifts.
55	extracter hooks and pins.
4,418	files.
2	sets fire-irons.
21	hay forks.
5	tin funnels.
2	water gauges.
9	gauges.
20	steam gauges.
2	gauge columns.
2	glaziers' diamonds.
6	grindstones.
60,191	pounds grindstones.
2	grass hooks.
12	gouges.
2	sets gouges.
1,587	handles.
69	hoes.
22	hatchets and hammers
1	iron-jointer
61	assorted knives.
2	iron kettles.
1	level and plumb.
10	ladders.
20	lathe-dogs.
124	melting ladles, 7 inches.
122	pouring ladles, 2½ inches.
1	lifting jack for wagons.
2	letters.
1	lubricator.
11	measures.
172	hickory mallets.
103	dogwood mallets.
4	milling wheels.
10	molder's flasks.
39	papers needles.
36	needles.
14	nail pullers.
1	pair cutting nippers.
15	nippers.
26	oil-stones.
290	oil cups and oilers.
1	plow.
10	plow-shares.
10	pails.
3	priming tools.

22	assorted punches.
22	planes.
3	plane irons.
5	pipe cutters.
22	pairs pliers.
2	glue pots.
4	solder pots.
5	fire pots.
2	push buttons.
1	rivet set.
99	rakes.
62	rasps.
40	rules.
42	brass riddles.
1	screw-plate and taps.
161	assorted saddlers' tools.
2	squares.
5	sand stones.
129	scythe-stones.
34	scythe-snaths.
12	scrapers.
1	screw-cutting tool.
11	sifters and sieves.
2	saw sets.
84	stencil dies, letters, and figures.
2	stencil plates.
23	pairs shears.
48	scythes and handles.
1	stock.
1	scale and weights.
3	scales.
414	shovels.
73	steel stamps.
153	saws.
34	saw-blades.
288	sash tools.
12	screw-drivers.
6	spades.
1	store truck.
2	turning tools.
3	sets tongs.
6	tape-lines.
12	taps.
1	tap and reamer.
2	tinner's tools.
5	trowels.
19	rat and mouse traps.
1	tap-borer.
7	vises.
1	watering pot.
7	wire gauges.
18	wrenches.
83	wheelbarrows.
1	wire cutter.
1	water injector.
107	assorted tools.
7	assorted utensils.

APPENDIX 3.

***Statement** of ordnance, ordnance stores, &c., issued to the military establishment, exclusive of the militia, during the fiscal year ended June* **30, 1883.**

CLASS I.

1	Gatling gun, short, 5 barrels, caliber .45.
4	Hotchkiss revolving guns, caliber 1.50.
4	6-pounder bronze guns.
28	3-inch rifled guns.
6	12-pounder guns, light.
4	8-inch Rodman guns.
7	8-inch siege mortars.
9	10-inch siege mortars.

CLASS II.

4	1.5-inch Hotchkiss revolving-gun carriages.
1	6-pounder gun carriage, complete.
27	3-inch gun carriages, complete.
1	3-inch gun carriage, without limber.
8	light 12-pounder gun carriages, complete.
5	8-inch casemate carriages and chassis.
1	10-inch casemate carriage and chassis.
2	15-inch barbette carriage and chassis.
7	8-inch mortar beds.
9	10-inch mortar beds.
5	6-pounder caissons and limbers.
21	3-inch caissons and limbers.
4	12-pounder caissons and limbers.
7	Laidley cavalry forge carts.
2	portable cavalry forges.
4	traveling forges A and limbers.
1	tripod for Gatling gun.
4	battery wagons and limbers.
2	mortar wagons.

CLASS III.

15	elevating arcs, indices, and pointers, 8-inch rifle.
3	elevating arcs and indices, 15-inch gun.
182	harness bags.
14	elevating bars.
8	maneuvering bars.
14	pinch bars.
23	baskets for mortar implements.

14	pass boxes.
3	wooden forge buckets.
16	iron sponge buckets.
33	wooden sponge buckets.
37	iron tar-buckets.
135	gutta-percha water buckets.
32	iron watering buckets.
1	leather water bucket.
2	papier-maché water buckets.
2	drag-ropes.
2	fuse-augers.
10	fuse-blocks.
26	fuse-cutters.
2	fuse-extractors.
7	fuse-gouges.
11	fuse-mallets.
2	fuse-rasps.
8	fuse-saws.
20	fuse-wrenches.
5	gunners' calipers.
55	gunners' gimlets.
61	gunners' haversacks.
3	gunners' levels.
17	gunners' pincers.
20	gunners' quadrants.
79	pairs gunners' sleeves.
4	iron handspikes, 15-inch gun.
72	maneuvering handspikes.
2	mortar-wagon handspikes.
4	shod handspikes.
62	trail handspikes.
66	sets artillery harness, 2 lead horses.
58	sets artillery harness, 2 wheel horses.
2	sets harness for Gatling gun cart, 2 horses.
5	sets harness for Laidley cavalry forge.
10	shell hooks.
36	tow hooks.
8	common lanterns.
19	dark lanterns.
30	globe lanterns.
4	magazine lanterns.
153	lanyards.
36	paulins, 5 by 5 feet.
12	paulins, 6 by 10 feet.
12	paulins, 8 by 10 feet.
105	paulins, 12 by 15 feet.
21	pendulum hausses, 3-inch gun.
18	pendulum hausse pouches.
2	pendulum hausse seats, 12-pounder howitzer.
31	plummets.
27	pointing cords.
16	sight pouches.
8	powder-funnels.
69	priming wires for field guns.
43	priming wires for siege guns.

25	prolonges.
4	quoins.
2	rammers and staves, 3-inch rifle.
6	rammers and staves, 8-inch rifle.
2	scrapers, gun.
6	scrapers, mortar.
7	scrapers, shell.
15	breech sights, 8-inch rifled gun.
2	breech sights, 15-inch gun.
2	muzzle or front sights, 3-inch rifle.
15	muzzle or front sights, 8-inch rifle.
2	shot-carriers.
18	cannon spikes.
76	sponge-covers, 3-inch rifle.
16	sponge-covers, 12-pounder gun.
3	sponges and rammers, 6-pounder gun.
104	sponges and rammers, 3-inch rifle.
40	sponges and rammers, 12-pounder gun.
18	sponges and rammers, mountain howitzer.
3	sponges and rammers, 8-inch siege mortar.
4	sponges and staves, 100-pounder gun.
10	sponges and staves, 8-inch rifle.
1	sponge and stave, 10-inch gun.
2	sponges and staves, 15-inch gun.
100	securing staves.
51	thumbstalls.
3	tompions, 6-pounder gun.
27	tompions, 3-inch rifle.
19	tompions, 12-pounder gun.
1	tompion, 12-pounder field howitzer.
1	tompion, 12-pounder mountain howitzer.
4	tompions. 4½-inch gun.
1	tompion, 8-inch rifle.
7	tompions, 8-inch gun.
3	tompions, 8-inch mortar.
1	tompion, 10-inch gun.
3	tompions, 10-inch mortar.
1	tompion, 13-inch mortar.
7	tompions, 15-inch gun.
18	trestles for pointing mortars.
51	tube pouches.
4	water tubs.
49	vent covers, field guns.
1	vent cover, 8-inch rifle.
3	vent covers, 8-inch mortar.
2	vent covers, 10-inch mortar.
34	vent pieces.
18	vent punches.
67	wipers for mortars.
15	worms and staves.
50	feed cases, Gatling gun.
8	gun covers, Gatling gun.
4	sets accessories for Hotchkiss revolving gun.
4	crosses and pistol grips for Hotchkiss revolving gun.
2	sets loading tools for Hotchkiss revolving gun.

CLASSES IV AND V.

350	3-inch shot.
380	12-pounder shot.
50	4½-inch shot.
410	30-pounder shot.
710	8-inch shot, Butler's.
382	100-pounder shot, Parrott's.
400	15-inch shot.
8	15-inch steel shot.
5,000	1.5-inch shell and metallic cases, Hotchkiss.
370	1.65-inch shell, Hotchkiss.
1,780	3-inch shell.
566	12-pounder shell.
335	30-pounder shell.
192	4½-inch shell.
395	100-pounder shell.
85	8-inch shell.
93	10-inch shell.
85	15-inch shell.
5	20-inch shell.
640	3-inch case shot.
644	12-pounder case shot.
715	3-inch canister.
538	12-pounder canister.
10	8-inch canister.

CLASS VI.

614	Springfield carbines.
50	Springfield rifles, 28-inch barrel.
2,282	Springfield rifles.
30	Springfield rifles, long range.
628	Springfield shot guns.
1,359	Colt's revolvers.
226	Schofield's Smith & Wesson revolvers.
287	artillery sabers.
305	cavalry sabers.
23	mounted officers' sabers.
40	musicians' swords.
93	non-commissioned officers' swords.
4	officers' swords.
4	sword bayonets.
10	rifleman's knives.
12	hunting knives.

CLASS VII.

80	artillery knapsacks.
309	artillery saber belts and plates.
90	carbine cartridge pouches.
1,503	carbine slings.
1,016	carbine sling swivels.
45	pistol cartridge pouches.
1,813	pistol holsters.
11	saber attachments.
2,104	saber belts.

2,079	saber belt plates.
1,233	saber knots.
3,153	bayonet scabbards.
439	blanket bags with coat straps.
2,006	blanket-bag coat straps.
989	blanket bags with shoulder straps.
886	blanket-bag shoulder straps.
1,462	blanket and coat straps.
91	sets blanket and coat straps.
18	brace yokes and stay straps.
7,697	canteens.
577	canteens and straps.
447	canteen chains.
441	canteen corks.
2,976	canteen covers.
7,881	canteen straps.
40	triangular pieces for canteens.
189	cap pouches.
153	carrying braces.
7,414	cartridge belts.
5,588	cartridge-belt plates.
3,100	cartridge boxes.
6,940	clothing bags.
5,834	clothing-bag straps.
6,548	forks.
20	sliding frogs.
368	great-coat straps.
3,296	gun slings.
5,552	haversacks.
2,866	haversacks and straps.
5,537	haversack straps.
132	hunting-knife scabbards.
7,037	knives.
6,998	meat cans.
500	pistol carriers with button screws and rivets and burrs.
1,649	revolver belts.
6,807	spoons.
6,958	tin cups.
8	valises.
3,512	waist belts.
3,510	waist-belt plates.
60	waist belts and plates, N. C. O. and musicians.

APPENDAGES.

137	brushes and thongs.
98	bullet molds.
1,781	headless shell extractors.
499	jointed ramrods.
2,998	screw-drivers.
1	screw-driver and cone wrench, pistol.
690	screw-drivers, revolver.
21	screw-drivers and hoof hooks, Schofield's.
230	screw-drivers, shot-gun.
81	spring vises.
321	tumbler punches.

1	wiper for rod bayonet.
1,980	wiping rods, wood.
20	wiping rods, pistol.
20	wiping rods, shot-gun.
608	wiping rods, sectional, shot-gun.

HORSE EQUIPMENTS.

213	curb bits, cavalry.
1,953	curb bridles, cavalry.
1,297	watering bridles.
40	brush and shoe pouches.
150	carbine loops.
130	carbine sockets.
570	carbine sockets and straps.
41	cruppers.
2,980	curry combs.
30	forage sacks.
39	girths.
751	hair cinchas or girths.
1,824	halters.
136	halter chains.
3,673	halter straps.
4,448	horse brushes.
100	horse covers.
281	horse covers with surcingles attached.
70	horse equipment covers.
1,408	lariats.
731	links.
2,332	nose bags.
1,301	picket pins.
50	rifle and ammunition boots.
804	saddles, cavalry.
32	saddle bags, canvas.
1,013	saddle bags, pattern 1879.
3,722	saddle blankets.
402	saddle cloths, felt.
20	saddle cloths, hair.
1,544	side lines.
190	spurs and straps, Mills'.
2,839	spurs.
3,195	spur straps.
370	stirrups.
538	stirrup straps.
4	stirrups with guidon sockets.
1,718	surcingles.
112	sweat leathers.

CLASS VIII.

SMALL-ARM AMMUNITION.

708,000	carbine ball cartridges.
2,817,280	rifle ball cartridges.
807,548	revolver ball cartridges.
295,100	rifle blank cartridges.

302,880	revolver blank cartridges.
301,000	round balls.
2,000	carbine bullets.
3,294,000	rifle bullets.
56,000	revolver bullets.
63	pounds elongated balls.
900	pounds round balls.
3,535,800	cartridge primers.
1,000	rifle cartridge shells.
29,100	shot-gun cartridge shells.
29,050	pounds sporting shot.
1,417,000	carbine cartridge wads.
1,162,000	paper wads.

AMMUNITION FOR CANNON.

6,304	blank cartridges, ½-pound charge.
1,203	blank cartridges, 1-pound charge.
930	blank cartridges, 2-pounds charge.
3,569	blank cartridges, 6-pounder gun.
19,770	blank cartridges, 3-inch gun.
10,850	blank cartridges, light 12-pounder gun.
500	blank cartridges, heavy 12-pounder gun.
3,700	assorted paper fuzes.
410	assorted wood fuzes.
27,800	pounds cannon powder.
7,600	pounds hexagonal powder.
6,000	pounds mammoth powder.
300	pounds mealed powder.
24,300	pounds mortar powder.
40,090	pounds musket powder.
2,250	electric primers.
117,710	friction primers.
½	pound slow match.
6	yards slow match.
8	grommet wads.

CLASS IX.

36	assorted blocks.
2	double blocks.
40	quarter blocks.
1	single block.
5,381	marksman's buttons.
3	capstans.
4	capstan bars.
7	sling chains.
62	gun chocks.
50	roller chocks.
90	wheel chocks.
580	field cases, for shot-gun supplies.
2,086	powder canisters.
10	disks.
2	gin falls.
182	streamers.
314	signal flags.
1	pressure gauge, Woodbridge.

1	field and siege gin.
85	halyards with screw eyes.
3	hydraulic jacks.
4	trunnion loops.
295	shot marks.
15	shot markers and staves.
16	shifting planks.
6	way planks.
11	platforms, siege gun.
13	platforms, mortar.
128	arm racks.
2	half rollers.
18	long rollers.
20	short rollers.
3	sheaves.
2	skids.
1	gin-sling, field gun.
2	gin slings, garrison gun.
1	firing stand.
365	stencil outfits, complete.
16	targets, Brinten's.
4	targets, cotton cloth.
188	targets, Laidley's.
24, 128	targets, paper.
2	target axles.
50, 478	target centers.
200	target cross-pieces.
846	target frames.
6	target nave-boxes.
7, 713, 500	target pasters.
29	target trucks, Cushing's.
95	target uprights.
2	trace ropes.
3	store trucks.

RELOADING TOOLS, ETC.

94	sets reloading tools, hand.
2	sets reloading tools, Winchester.
129	crimping die caps.
494	powder charges.
9	powder charges, bench.
272	powder and shot chargers, adjustable.
750	rifle cleaners.
40	crimping dies.
42	reloading dies.
65	resizing dies.
119	drifts.
538	drifts, No. 20.
59	primer extractors.
7	formers for paper shells.
81	funnels.
538	funnels No. 20.
253	primer extractor hooks.
98	melting ladles.
96	pouring ladles.

77	mallets.
1	powder measure.
38	oil cups.
1,189	primer extractor pins.
38	primer punches.
68	reloading die punches.
53	resizing die punches.
47	shell scrapers.
40	primer setters.
40	safety sockets.
3	strainers.
602	priming tools, Frankford.
44	priming tools, Bridgeport.
16	washers, reloading and crimping die.
123	washers, reloading punch.
60	wiping rods.
109	brush wipers.
538	brush wipers No. 20.

Class X—I.

3	feed guides, Gatling gun.

Class X—II.

1	air cylinder plug with chain for 15-inch carriage.
1	axle body.
16	nave bands.
8	tire bands.
20	bolts, A No. 1.
60	tire bolts.
2	foot boards, limber.
6	feet chain.
2	collars, handspike socket, 15-inch gun carriage.
3	elevating-screws.
80	fellies.
1	fulcrum, mortar bed.
1	hub, bronze, cavalry forge.
20	keys, ammunition chest.
5	keys, stay-pin, caisson.
8	pounds nails.
284	nuts, assorted.
51	linchpins.
5	stay-pins, caisson.
35	poles.
9	pole clips and loops.
15	pole yokes.
4	rails, caisson.
3	shafts, cavalry forge.
4	splinter bars.
1	splinter-bar Gatling gun carriage.
3	stocks, battery wagon.
3	stocks, caisson.
128	spokes.
176	washers.
41	washers, linch.
73	wheels, complete.
2	wheels, cavalry forge.
4	wheels, Hotchkiss mountain gun carriage.

CLASS X—III.

24	curb bits, artillery.
36	bridles, artillery.
846	buckles, brass plated.
1,425	buckles, iron, roller.
76	collars.
4	collars and hames, adjustable.
2	collars, Berry.
56	girths, drivers' saddle.
75	halters.
12	halter chains.
35	halter straps.
4	hames, pairs.
100	hame straps.
62	links, cold, shut.
12	nose bags.
81	pole pads.
142	pole straps.
60	rammer head, 3-inch gun.
16	rammer heads, 12-pounder howitzer.
20	reins.
77	rosettes, artillery bridle.
1	saddle gun carriage.
69	sponge heads, 3-inch gun.
16	sponge heads, 12-pounder howitzer.
25	sponges, woolen, assorted.
30	sponges, woolen, 6-pounder gun.
278	sponges, woolen, 3-inch gun.
28	sponges, woolen, 4½-inch gun.
89	sponges, woolen, 12-pounder gun.
5	sponges, woolen, mountain howitzer.
20	sponges, woolen, 32-pounder gun.
16	sponges, woolen, 15-inch gun.
24	staves, rammer and sponge.
4	stirrups, artillery.
70	surcingles, artillery.
6	traces for patent splinter-bar.
44	traces, lead.
60	traces, wheel.
226	whips, artillery.

CLASS X—IV.

50	sabots, 8-inch Butler shot.
200	sabots, 10-inch Columbiad.
100	tin straps, 10-inch Rodman.

CLASS X—VI.

PARTS SPRINGFIELD CARBINE.

6	barrels, complete.
54	bands.
20	band springs.
1	breech screw.

1	bridle screw.
6	butt plate screws.
58	cam latch springs.
62	ejector springs.
36	ejector spring spindles.
10	ejector studs.
16	extractors.
51	firing pins.
50	firing pin screws.
218	front sights.
93	front sight covers.
65	front sight pins.
100	guard bow nuts.
6	guard screws.
6	hammers.
20	main springs.
10	main spring swivels.
10	main spring swivel rivets.
295	rear sights, complete.
6	rear sight bases.
60	rear sight base screws.
291	rear sight leaves.
60	rear sight plates, buck-horn.
10	rear sight slides.
40	rear sight slide blocks.
384	rear sight slide gibs.
20	rear sight slide plates.
40	rear sight slide screws.
30	rear sight slide springs.
41	sears.
20	sear screws.
21	sear springs.
10	sear spring screws.
8	side screws.
474	stocks, complete.
186	stocks, wood part.
6	tang screws.
47	tumblers.
72	tumbler screws.

PARTS SPRINGFIELD RIFLE.

131	bands, lower.
181	bands, upper.
44	band springs.
34	barrels, complete.
65	bayonets.
47	bayonet clasps.
216	bayonet clasp screws.
51	breech blocks.
185	breech block caps.
437	breech block cap-screws.
74	breech screws.
377	bridles.
396	bridle screws.
1	butt plate.

12	butt plate screws.
143	cam latches.
475	cam latch springs:
901	ejector springs.
872	ejector spring spindles.
128	ejector studs.
1,106	extractors.
2,194	firing pins.
633	firing pin screws.
147	front sights.
66	front sight pins.
1	guard, complete.
73	guard bow swivels.
162	guard bow swivel screws.
86	guard screws.
42	hammers.
118	hinge pins.
63	hinge-pin studs.
5	locks.
259	main springs.
575	main-spring swivels.
539	main-spring swivel rivets.
1,562	pistol grips, metallic.
122	pistol grips, wood.
5	pistol grip screws.
259	ramrods.
66	ramrod stops.
5	receivers.
355	rear sights.
12	rear sight bases.
96	rear sight base screws.
40	rear sight base springs.
546	rear sight leaves.
4,487	rear sight plates, buck-horn.
403	rear sight center pins.
53	rear sight joint pins.
87	rear sight slides.
33	rear sight slide blocks.
70	rear sight slide gibs.
34	rear sight slide plates.
51	rear sight slide screws.
260	rear sight slide springs.
29	rear sight slide spring rivets.
835	sears.
318	sear screws.
296	sear springs.
95	sear spring screws.
225	side screws.
70	side screw washers.
255	stocks, complete.
514	stocks, wood part.
352	tang screws.
32	thumb pieces.
50	tips for stocks.
50	tip screws.
151	triggers.

20	trigger screws.	
1,002	tumblers.	
72	tumblers, swiveled.	
504	tumbler screws.	
1	lower band	cadet rifle, model, 1869.
1	ramrod	
322	stocks, wood part, Hotchkiss carbine.	
24	stocks, wood part, Hotchkiss rifle.	
25	stocks, wood part, Hotchkiss Navy rifle.	

PARTS COLT'S REVOLVER.

50	back straps.
189	back-strap screws.
43	bolts.
65	bolt screws.
80	center pins.
116	center-pin bushings.
147	center-pin catch screws.
167	center-pin screws.
6	cylinders.
143	ejector heads.
158	ejector rods.
244	ejector springs.
88	ejector tubes.
100	ejector-tubes crews.
136	firing pins.
124	firing-pin rivets.
69	front sights.
57	gates.
72	gate catches.
117	gate-catch screws.
147	gate springs.
50	guards.
137	guard screws, long.
115	guard screws, short.
104	hammers.
105	hammer cams.
141	hammer rolls.
129	hammer-roll rivets.
117	hammer screws.
137	hands.
144	hand springs.
144	mainsprings.
144	mainspring screws.
6	recoil plates.
88	sear springs.
34	sear-spring screws.
103	sear and stop bolt springs.
87	sear and stop bolt spring screws.
45	stop-bolt screws.
47	stocks.
92	triggers.
134	trigger screws.

PARTS SCHOFIELD, SMITH & WESSON REVOLVERS.

10	hammers.
10	trigger pins.
10	trigger springs.
10	trigger-spring pins.

PARTS BREECH-LOADING SHOT-GUN.

2	ejector springs.
2	ejector-spring spindles.
2	extractors.

PARTS OF SWORDS.

10	scabbards, steel, musicians'.
8	scabbards, steel, non-commissioned officers'.
4	scabbards, nickel-plated, officer's sword.

CLASS X—VII.

6,243	buckles, bar, brass.
3,402	buckles, brass-wire.
925	buckles, bar, iron.
1,422	buckles, roller, iron.
360	bolts, halter.
1,424	fasteners, side line.
8	frogs and loops, bayonet-scabbard.
25	hooks and bands, saber-belt, brass.
845	hooks, double spring, lariat.
50	hooks, snap, halter-chain.
110	hooks, snap, large.
819	hooks, snap, saber-belt, brass.
400	loops, curb-strap.
440	loops, footman.
60	nails, saddle.
2,500	bridle ornaments.
1,864	ovals.
42	reins.
1,100	rings, D, brass.
432	rings, D, iron.
1,110	rings, brass.
636	rings, halter.
20	rings, halter, swiveled.
528	rings, iron.
50	screws, ball mold.
500	shields.
744	squares, halter.
504	staples, foot, brass.
2,754	staples for rings, brass.
520	straps, cincha.
1,760	straps, coat.
177	straps, curb.
142	straps, hook.
168	yards girth webbing, 4½ inches wide.
272	yards linen webbing, 4 inches wide.
60	yards linen webbing, 7½ inches wide.

Class X—VIII.

500	cartridge bags, ½-pound charge.
1,500	cartridge bags, 2-pounds charge.
2,000	cartridge bags, 6-pounder gun.
13,210	cartridge bags, 3-inch gun.
6,000	cartridge bags, 12-pounder gun.
2,000	cartridge bags, mountain howitzer.
3,200	cartridge bags, 4½-inch gun.
600	cartridge bags, 20-pounder gun.
600	cartridge bags, 30-pounder gun.
200	cartridge bags, 32-pounder gun.
500	cartridge bags, 100-pounder gun.
940	cartridge bags, 8-inch rifled gun.
100	cartridge bags, 8-inch Rodman gun.
1,450	cartridge bags, 10-inch gun.
550	cartridge bags, 15-inch gun.
400	fuse plugs.

Class X—IX.

2	alidades, plane table.
2	arcs, plane table.
3	gin shoes.

PART SECOND: CLOTH, ROPE, THREAD, ETC.

100	yards burlaps.
7,289⅝	yards cotton cloth.
20	yards duck.
64	yards sponge material.
43	pounds lanyard cord.
6	pieces sash cord.
218⅞	pounds sash cord.
125	pounds cotton waste.
27½	pounds lampwicking.
56½	pounds marline.
10	pounds hemp packing.
1,769	pounds rope, hemp and manila.
15	pounds thread, assorted.
154	pounds thread, linen.
3	pounds thread, saddlers'.
612½	pounds thread, shoe.
313½	pounds tow.
263	pounds twine.
30	pounds twine, rocket.
2	pounds rope yarn.

IRONMONGERY.

20	pounds iron brads.
5	feet chain.
100	gas checks.
5	cocks, assorted.
1,000	pressure discs.
124	double S hooks.
5,100	horseshoes.

7,574	pounds horseshoes.
1,594	pounds bar iron.
62	cold shut links.
6	locks, assorted.
1,330	pounds horseshoe nails.
3,819	pounds iron nails.
672	Japanned nails.
231	padlocks.
89	gross escutcheon pins.
177	pounds brass rivets and burrs.
580	pounds copper rivets and burrs.
93	pounds iron rivets and burrs.
87$\frac{17}{18}$	gross brass screws.
84	gross iron screws.
50	iron screws, brass heads.
10	pounds solder.
1	ounce silver solder.
200	pounds spikes.
268	pounds bar steel.
54,000	copper tacks.
34	papers copper tacks.
31	pounds copper tacks.
813,000	iron tacks.
887	papers iron tacks.
13	pounds iron tacks.
1	box sheet tin.
458	pounds cast-iron truck wheels.
30	pounds iron wire.

LEATHER, ETC.

297	quarts blacking.
239½	pounds black wax.
45	ounces bristles.
6	pounds calfskin.
10	pounds hair for collar pads.
874	sides bridle leather.
401	pounds collar leather.
3	sides collar leather.
18,819	pounds harness leather.
4	sides lacing leather.
6	sheepskins.

LUMBER.

11,752	feet boards.
1,311	feet plank.
3,986	feet scantling.
4,700	feet timber.

HEATING, CLEANING, ETC.

108	bath bricks.
276	corn brooms.
4	split brooms.
22	counter brushes, dusting.
30	button brushes.

3	wire scratch brushes.
10	button sticks.
89	pounds candles.
51	boxes cleaning material.
52	chamois skins.
65 7/12	quires crocus cloth.
1,124¼	quires emery cloth.
8,450	pounds coal.
6	feather dusters.
25 1/12	quires emery paper.
6½	pounds polishing material.
6½	pounds scouring material.
325½	gallons kerosene oil.
434	pounds rottenstone.
78	quires sandpaper.
180	pounds bar soap.
1,727	pounds castile soap.
95½	pounds sponge.
770	papers tripoli.

MATERIALS FOR OFFICE USE.

12	boxes elastic bands.
2	waste-paper baskets.
36	instruction books.
10	fitch brushes.
2	boxes crayons.
1,100	envelopes.
12	pieces india rubber.
12	pints black ink.
3	inkstands.
36	sheets blotting paper.
½	ream cap paper.
1½	reams letter paper.
2	reams note paper.
510	pounds wrapping paper.
72	pencils.
1	gross steel pens.
24	pen holders.
2	seal stamps.
50	pounds sealing wax.
200	shipping tags.
1	tape measure.

LABORATORY STORES.

½	pint muriatic acid.
12	pounds muriatic acid.
84	pounds sulphuric acid.
99	gallons alcohol.
100	pounds gum arabic.
155¾	pounds beeswax.
1	glass bottle.
57	pounds camphor.
70	pounds white chalk.
200	pounds charcoal.
50	pounds ammoniated copper.

20	pounds sulphate of copper.
1	dynamometer.
2	finger cots.
1	barrel flour.
1,000	pounds refined niter.
543	pounds cartridge paper.
50	pounds log paper.
12	sheets petroleum paper.
600	pounds of rocket paper.
20	pounds black pepper.
336	pounds chlorate of potash.
2	shears.
100	pounds nitrate of strontia.
300	pounds sulphur.
20	pounds tobacco.
2,609	pounds Japan wax.
40	gallons whisky.

OILS, PAINTS, ETC.

7	barrels coal tar.
263	gallons coal tar.
83½	gallons Japan drier.
205	gallons lacker.
60	pounds lampblack.
115	pounds red lead.
1,727½	pounds white lead.
13	pounds extract of logwood.
5	pounds oak graining.
10	gallons yellow ocher.
82	quarts cosmoline oil.
3,962	pounds harness oil.
15	gallons lard oil.
951	gallons linseed oil.
136	gallons neat's-foot oil.
40	gallons neutral oil.
2	gallons olive oil.
886	gallons sperm oil.
1,169¼	pounds black paint.
2	pounds Prussian blue paint.
50	pounds green paint.
410	pounds lead-color paint.
3,077	pounds metallic paint.
3,793	pounds olive paint.
575	pounds red paint.
10	gallons chrome-yellow paint.
2	boxes stencil paste.
120	pounds putty.
5	pounds Indian red.
2	pounds Venetian red.
5	pounds vermilion red.
654	gallons turpentine.
25	pounds umber.
3	gallons coach varnish.
22	gallons copal varnish.
7	pounds vermilion.
30	pounds whiting.

MISCELLANEOUS.

50	barrels, powder, metallic.
969	barrels, powder, wood.
2	boards, specimen cartridges.
1	board, specimen primers.
58	boxes, forge and battery wagon stores.
38	boxes, reloading tools.
283	cans, tin.
396	canisters, tin.
18	chamois skin cases, saber.
9	chamois-skin cases, sword.
197	arm chests.
2	forge chests.
1	tool chest.
1,329	pounds grease, wheel.
1	set harness, ambulance.
2,000	barrel hoops, wood.
108	powder kegs.
96	corn sacks.

MACHINES AND INSPECTING INSTRUMENTS.

1	magneto-electric machine.
300	copper cylinders.
1	crusher gauge.
2	pressure gauges.
1	ring gauge.

TOOLS.

4	adzes.
4	anvils.
25	aprons.
14	augers.
1	set augers with patent handles.
12	auger handles.
69	awls, assorted.
22	awls, brad.
5	awls, peg.
387	awls, saddlers'.
2	awls, scribing.
2	awls, seat.
4	awls, strap.
1	awl, stub.
241	awl handles.
23	awl handles, patent.
4	axes, assorted.
3	axes, broad.
36	axes, felling.
7	axes, hand.
15	ax handles.
8	bill hooks.
154	bits, for brace.
1	set bits.
2	boxes, dredging.
3	boxes, shoeing.
9	braces.

26	brushes, flat.
6	brushes, hard.
3	brushes, letter-press.
4	brushes, marking.
310	brushes, paint.
30	brushes, paste.
135	brushes, sash.
4	brushes, stencil.
2	brushes, varnish.
10	buckets, tin.
4	buttresses.
4	calipers, smiths'.
28	chalk lines.
4	channelers.
2	chisels.
11	chisels, cold, handled.
8	chisels, cold iron, hand.
18	chisels, firmer.
9	chisels, framing.
6	chisels, hot iron, hand.
24	chisel handles.
24	clamps, saddlers'.
10	claw tools.
4	clinching irons.
42	compasses.
4	creasers, smiths'.
54	creasers, wood.
4	dies, assorted.
3	die stocks with dies and taps, complete.
1	die stock and tap wrench.
12	drills.
37	edge tools.
729	files.
62	file handles.
2	forges, cavalry, with tools, complete.
4	fullers.
13	gauges.
26	gimlets.
12	gouges.
6	grindstones.
6	grindstone arbors and cranks.
1	grindstone fixtures, set.
6	grindstone stands.
5	hammers, assorted.
10	hammers, claw.
4	hammers, copper.
11	hammers, hand.
3	hammers, nailing.
22	hammers, riveting.
32	hammers, saddlers'.
12	hammers, shoeing.
7	hammers, sledge.
1	hammer, smiths'.
3	hand barrows.
4	hardies.
15	hatchets.

34	horses, saddlers'.
12	jackscrews.
5	knives, assorted.
1	knife, channel.
1	knife, drawing.
16	knives, gauge, draw.
2	knife blades for gauge knife.
18	knives, half-round.
16	knives, head.
56	knives, shoe.
23	knives, shoeing.
21	knives, splitting.
7	knives, toe.
3	loop sticks.
32	mallets.
4	nail claws.
32	needles, collar.
5	needles, glovers', papers.
9,138	needles, saddlers'.
40	nippers, cutting.
8	oil droppers.
20	oil stones.
6	oil stone slips.
1	palm, collar, saddlers'.
6	pans, dust.
26	pickaxes, handled.
2	pickax handles.
13	pincers.
21	planes.
8	plane irons.
9	pliers.
4	pokers.
1	pot, glue.
8	pricking carriages.
21	pricking wheels.
4	pritchels.
105	punches, assorted.
37	punches, spring.
3	rakes.
167	rasps.
8	reaping hooks.
2	reels, chalk line.
33	rivet sets.
4	rounding irons.
57	rules.
27	sandstones.
40	saws.
12	saw blades.
6	saw sets.
3	scales.
10	scissors.
54	screw drivers.
6	screw taps.
1	scriber.
16	scythes.
16	scythe snaths.

16	scythe stones.
38	shears.
10	shovels, assorted.
32	shovels, long-handled.
11	sickles.
5	sieves.
22	slickers.
28	pairs slippers, magazine.
24	spades.
4	spokeshaves.
14	squares.
3	sets stencil plates, letters and figures.
33	thimbles.
6	ticklers.
9	tool bags, saddlers' and smiths' tools.
16	tongs.
14	vises, assorted.
13	wrenches, assorted.

APPENDIX 4.

Apportionment of ordnance, ordnance stores, &c., for the fiscal year ending June 30, 1883, *under sections* 1661 *and* 1667, *Revised Statutes United States, and regulations established in conformity therewith.*

States and Territories.	Number of Senators and Representatives.	Money-value.
Alabama	10	$4,797 85
Arkansas	6	2,878 71
California	6	2,878 71
Colorado	3	1,439 36
Connecticut	6	2,878 71
Delaware	3	1,439 36
Florida	4	1,919 14
Georgia	11	5,277 64
Illinois	21	10,075 49
Indiana	15	7,196 78
Iowa	11	5,277 64
Kansas	5	2,398 93
Kentucky	12	5,757 42
Louisiana	8	3,838 28
Maine	7	3,358 50
Maryland	8	3,838 28
Massachusetts	13	6,237 21
Michigan	11	5,277 64
Minnesota	5	2,398 93
Mississippi	8	3,838 28
Missouri	15	7,196 78
Nebraska	3	1,439 36
Nevada	3	1,439 36
New Hampshire	5	2,398 93
New Jersey	9	4,318 06
New York	35	16,792 48
North Carolina	10	4,797 85
Ohio	22	10,555 27
Oregon	3	1,439 36
Pennsylvania	29	13,918 76
Rhode Island	4	1,919 14
South Carolina	7	3,358 50
Tennessee	12	5,757 42
Texas	8	3,838 28
Vermont	5	2,398 93
Virginia	11	5,277 64
West Virginia	5	2,398 93
Wisconsin	10	4,797 85
Arizona Territory[*]	3	1,439 36
Dakota Territory[*]	3	1,439 36
Idaho Territory[*]	3	1,439 36
New Mexico Territory[*]	3	1,439 36
Montana Territory[*]	3	1,439 36
Utah Territory[*]	3	1,439 36
Washington Territory[*]	3	1,439 36
Wyoming Territory[*]	3	1,439 36
District of Columbia[*]	3	1,439 36
Total	396	189,995 00
Freights, &c.	....	10,005 00
		200,000 00

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[*] Apportionment according to the first paragraph of the President's regulation of April 30, 1855.

APPENDIX 5.

Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1882, *to June* 30, 1883, *under sections* 1661 *and* 1667, ***Revised Statutes United States.***

CLASS I.

12	3-inch wrought-iron rifled guns, model 1861.
4	Gatling guns, 10 barrels, long, caliber 45.

CLASS II.

12	carriages and limbers for 3 inch guns.
4	carriages and limbers for Gatling guns, caliber .45.
8	caissons and limbers for 3-inch guns.
2	caissons and limbers for 6-pounder guns.

CLASS III.

3	fuse wrenches.
2	fuse blocks.
2	fuse cutters.
2	fuse gouges.
100	feed cases.
23	gunners' haversacks.
12	gunners' gimlets.
10	gunners' pincers.
22	handspikes, trail.
59	lanyards for friction primers.
8	muzzle-sights for 3-inch guns.
48	priming wires.
15	prolonges.
17	paulins, 12 by 15 feet.
19	pendulum hausses for field guns.
11	pendulum hausse pouches for field guns.
15	pendulum hausse seats, for field guns.
23	sets artillery harness, 2 horses, wheel.
15	sets artillery harness, 2 horses, lead.
12	sponge buckets, iron.
2	sponges and rammers, 12-pounder.
12	sponges and rammers, 6-pounder.
44	sponges and rammers, 3-inch gun.
3	sponge covers, 12-pounder gun.
8	sponge covers, 6-pounder gun.
44	sponge covers, 3-inch gun.
17	sponges, woolen, 12-pounder gun.
4	tar-buckets, iron.
12	tompions, 3-inch gun.

8	tow-hooks.
3	tube-pouch belts.
66	thumbstalls.
29	tube pouches.
23	vent covers.
15	vent punches.
7	worms and staves for field guns.
2	wheels, spare, No. 1, complete.
4	watering buckets.
2	port-fire stocks.

Classes IV, V.

45	10-inch mortar shell.
24	12-pounder shell.
36	12-pounder canister, filled.
350	3-inch solid shot.
50	3-inch case shot.
200	3-inch percussion shell.
200	3-inch canister.
50	3-inch shot, fixed.
25	3-inch case shot, fixed.
25	3-inch canister, filled and fixed.
100	3-inch Hotchkiss shot, fully prepared.
225	3-inch Hotchkiss shell, fully prepared.
125	3-inch Hotchkiss shell, time fuse.

Class VI.

2,283	Springfield rifles, caliber. 45.
50	Springfield carbines, caliber. 45.
154	Colt's revolvers, caliber. 45.
59	Schofield's Smith & Wesson's revolvers, caliber .45.
140	officers' swords.
121	non-commissioned officers' swords.
100	light artillery sabers.
13	cavalry sabers.
76	bayonets.

Class VII.

6,909	bayonet scabbards.
4,057	cartridge boxes.
400	waist belts.
3,170	waist belts and plates.
3,418	gun slings.
50	carbine slings.
50	carbine-sling swivels.
400	cartridge belts and plates.
5	non-commissioned officers' sword belts and plates.
60	swords knots.
588	saber belts and plates.
100	sliding frogs.
209	pistol holsters.
60	pairs spurs and straps.
100	blanket bags and straps.
143	bridles, curb.
24	halters and straps.

83	saddles, cavalry.
943	saddle blankets.
36	saddle cloths, felt.
10	saddle cloths, canvas.
2	pair saddle bags.
60	pair coat straps.
24	artillery whips.

Class VIII.

924	blank cartridges for 12-pounder gun.
1,000	blank cartridges for 6-pounder gun.
1,124	blank cartridges for 3-inch gun.
80,000	rifle blank cartridges, caliber .50.
183,000	rifle blank cartridges, caliber .45.
87,000	rifle ball cartridges, caliber .50.
1,581,500	rifle ball cartridges, caliber .45.
16,000	carbine ball cartridges, caliber .50.
15,000	musket blank cartridges, caliber .58.
1,000	revolver blank cartridges.
14,000	revolver ball cartridges, caliber .45.
7,500	lubricated bullets (500 grains).
4,000	round bullets.
16,000	friction primers.
10,000	cartridge primers.
100	fuses, 10-inch mortar shell.
200	time fuses.
5,000	cartridge shells (2″.4) caliber .45.
1,000	carbine blank cartridges, caliber .50.
200	pounds cannon powder.

Class X.

PARTS OF SPRINGFIELD RIFLE, CALIBER .45.

11	breech blocks.
30	breech-block caps.
110	breech-block cap screws.
25	bridles.
25	bridle screws.
25	bayonet clasps.
25	butt-plate screws.
25	cam latches.
225	cam-latch springs.
525	extractors.
325	ejector springs.
425	ejector-spring spindles.
1,875	firing pins.
125	firing-pin screws.
10	front sights.
10	front-sight rivets.
50	guard-bow nuts.
25	guard-bow swivels.
25	lock plates.
25	mainsprings.
25	mainspring swivels.

115	rear sights, complete.
100	rear-sight joint pins.
100	rear-sight base screws.
50	rear-sight leaves.
50	rear-sight leaf slides.
26	receivers.
525	ramrod stops.
205	sears.
75	sear springs.
125	sear-spring screws.
45	stocks.
280	tumblers.
25	tumbler screws.
10	thumb-pieces.

SPARE PARTS FOR SPRINGFIELD RIFLE, CALIBER .50.

10	rear-sight leaves.
10	rear-sight leaf slides.
13	stocks.
1	tumbler.
6	upper band swivels.
12	linchpins, No. 1.
12	linch washers, No. 1.
100	metallic pistol grips.

MISCELLANEOUS.

2	arm chests.
2	adjustable chargers, for rifle cartridges.
56	boxes, cleaning materials.
2	bullet moulds.
2	melting ladles, 7″.
2	pouring ladles, 2″.
2	sets reloading tools.

APPENDIX 6.

Statement of ordnance, ordnance stores, &c., distributed to the Territories, and States bordering thereon, from July 1, 1882, *to June* 30, 1883, *under the joint resolutions of July* 3, 1876, *March* 3, 1877, *and June* 7, 1878, *and the act of May* 16, 1878.

200	Springfield rifles, caliber .50.
200	leather bayonet scabbards.
400	cartridge boxes.
400	waist belts and plates.
10,000	rifle ball cartridges, caliber .50.

APPENDIX 7.

Statement of ordnance and ordnance stores, &c., distributed to colleges and universities from July 1, 1882, *to June* 30, 1883, *under section* 1225 *Revised Statutes, United States, as amended by act approved July* 5, 1876.

CLASS I.

2	3-inch wrought-iron rifled guns, model 1861.

CLASS II.

2	carriages and limbers for 3-inch guns.

CLASS III.

2	gunners' haversacks.
2	handspikes, trail.
4	lanyards.
2	priming wires.
2	paulins, 12 by 15 feet.
1	pendulum hausse.
1	pendulum hausse seat.
1	pendulum hausse pouch.
4	sponges and rammers for 3-inch rifle guns.
4	sponge covers for 3-inch rifle guns.
2	tube pouches.
4	thumbstalls.
2	tompions.
2	vent covers.
1	worm and staff, field.

CLASS VI.

80	Springfield rifles, caliber .45.
28	non-commissioned officers' swords.

CLASS VII.

80	cartridge boxes.
80	bayonet scabbards.
80	waist belts and plates.
20	waist belts and plates, N. C. O.

CLASS VIII.

200	blank cartridges for 12-pounder gun.
700	blank cartridges for 6-pounder gun.
710	blank cartridges for 3-inch gun.
6,000	carbine blank cartridges, caliber .50.
13,300	carbine blank cartridges, caliber .45.
6,000	carbine ball cartridges, caliber .50.
14,100	carbine ball cartridges, caliber .45.
5,500	friction primers.

APPENDIX 8.

Statement of ordnance stores issued to Executive Departments during the year ended June 30, 1883, *under the provisions of the act of March* 3, 1879.

TO THE PUBLIC PRINTER, WASHINGTON, D. C.

12 Colt's revolvers.
12 revolver holsters.
12 waist belts and plates.
96 revolver ball cartridges.

APPENDIX 9.

Report of action taken under the act of March 3, 1881, *during the fiscal year ended June* 30, 1883.

SOLD.

To A. J. Simpson.

1882.		
Aug. 11.	112 24-pounder boat howitzer shells, 386 24-pounder howitzer shells, $3\frac{1344}{2240}$ tons, at $12.55 per ton	$45 18
	190 24-pounder case shot, $1\frac{1601}{2240}$ tons, at $32.55 per ton	55 82
	180 32-pounder case shot, $2\frac{200}{2240}$ tons, at $36.55 per ton	76 37

To Paulding, Kemble & Co., under contract dated July 6, 1882.

262	200-pounder Parrott case shot.
389	200-pounder Parrott shells.
10,205	100-pounder Parrott shells.
1	9-pounder solid shot.
136	12-pounder solid shot.
1,500	24-pounder solid shot.
1,591	42-pounder solid shot.
1,132	32-pounder shells.
320	42-pounder shells.
2,162	8-inch mortar shells.
751	18-pounder grapeshot.
21,598	pounds canister shot.
189	20-pounder Parrott shot.
3,279	30-pounder Parrott shot.
206	32-pounder Parrott shot.
115	42-pounder Parrott shot.
5,127	100-pounder Parrott shot.
242	200-pounder Parrott shot.
2,745	100-pounder Parrott case shot.
3,671	10-pounder Parrott shells.
329	20-pounder Parrott shells.
9,636	30-pounder Parrott shells.
1,220	32-pounder Parrott shells.
37	24-pounder Parrott case shot.
59	32-pounder Parrott case shot.
194	20-pounder Parrott canister.
2,092	30-pounder Parrott canister.
889	100-pounder Parrott canister.
10,000	12-pounder spherical shells.
485	24-pounder spherical shells.
9	3-inch Dyer shot.
119	32-pounder Hotchkiss shells.
75	4.5-inch Hotchkiss case shot.
8	4.5-inch Absterdam shells.
27	32-pounder Brook's shells.
5	42-pounder James' shot.
64	42-pounder James' shells.
91	30-pounder Schenkls shells.
40	12-pounder boat-howitzer canister.
80	stands 24-pounder grapeshot.
373	stands 32-pounder grapeshot.

128	stands 42-pounder grapeshot.
628	6-pounder shot.
8,300	10-pounder Parrott case shot.
476	20-pounder Parrott case shot.
5,759	30-pounder Parrott case shot.
1	sling chain.
36	handspike rollers.
2	iron-casemate pintles.
1	screw-handle for sling cart.
1,874	32-pounder solid shot.
4,997	18-pounder shells.
10,025	24-pounder shells.
102	42-pounder shells.

Amounting in all to—

3,055,764 pounds cast iron, at $\frac{9}{10}$ cent per pound	$27,501	85
1,305 pounds wrought iron, at 1 cent per pound	13	05
63,899 pounds brass, at 10 cents per pound	6,389	90
44,800 pounds lead, at 4 cents per pound	1,792	00
4,350 pounds spelter, at 4 cents per pound	174	00

To J. W. Frazier.

1883.			
May 12.	15,300 pounds musket powder, from broken-up ammunition, at 8 cents per pound	1,224	00
	Total proceeds	37,272	27

PURCHASED.

From E. I. Du Pont de Nemours & Co.

1882.			
Sept. 27.	10,000 pounds musket powder, at 22 cents per pound	$2,200	00
Nov. 18.	10,000 pounds musket powder, at 22 cents per pound	2,200	00
Dec. 7.	30,000 pounds musket powder, at 22 cents per pound	6,600	00
1883.			
April 2.	10,000 pounds musket powder, at 22 cents per pound	2,200	00
May 1.	10,000 pounds musket powder, at 22 cents per pound	2,200	00
" 24.	20,000 pounds musket powder, at 22 cents per pound	4,400	00
June 20.	20,000 pounds musket powder, at 22 cents per pound	4,400	00
Jan. 13.	1,500 pounds square powder, at 25 cents per pound	375	00
	3,000 pounds hexagonal powder, at 25 cents per pound	750	00

From South Boston Iron Company.

1882.			
July 24. " 29.	1,000 8-inch Butler cored shot, 1,000 8-inch Butler cored shot, } 362,389 pounds, at 8 cents per pound	28,991	12
Aug. 15.	300 4.2-inch Butler shot, at $7.60 each	2,280	00
1883.			
Jan. 17.	36 8-inch Butler shells, at $36.58 each	1,316	88

From A. M. Sawyer.

Jan. 27.	1,000 3-inch Sawyer canister, at $1.50 each	1,500	00

From Paulding, Kemble & Co.

1882.			
Dec. 16.	2,000 8-inch Butler cored shot, 361,778 pounds, at 9½ cents per pound	34,370	81
	Total purchased	93,783	81

APPENDIX 10.

ON THE VALUE OF "C" IN DIDION'S FORMULA FOR COMPUTING THE TRAJECTORY OF A PROJECTILE IN AIR.

BY CAPT. JOHN E. GREER, ORDNANCE DEPARTMENT, U. S. A.

NATIONAL ARMORY, *October* 14, 1882.

SIR: Calculation of the remaining velocity of the service bullet at various ranges by Didion's formula, page 415, Benton's Ordnance and Gunnery, having given results differing somewhat from those obtained by the use of Bashforth's and Hélie's, it was thought the error—if it were due to Didion's formula at all—might be caused by the particular value of "*c*" used, and which value is supposed to be a constant for a particular bullet. The method proposed by Colonel Benton for determining the value of this constant by the electro-ballistic machine is fully explained on page 411 of the work referred to. By this method Captain Prince, Ordnance Department, after a very careful and elaborate series of experiments, Ordnance Notes, No. 4, to which reference is invited, deduced a value for "A" of .0004192, whence $c=1{,}943$.

On applying this value of "*c*" to the determination, for instance, of the angles of elevation of the service rifle at ranges of 100 to 1,000 yards by the formula

$$\tan \varphi=\frac{gX}{2V^2}B^*$$

page 416, Ordnance and Gunnery, there resulted the following:

Angles of elevation.

Range	100 yards.	200 yards.	300 yards.	400 yards.	500 yards.	600 yards.	700 yards.	800 yards.	900 yards.	1,000 yards.
	′ ″	′ ″	′ ″	′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
Angles of elevation	10 20	22 52	38 13	56 41	1 18 51	1 44 17	2 17 19	2 55 5	3 39 52	4 32 43

On page 29, Pamphlet Descriptive of the Springfield Rifle and Carbine, the following angles are given, these being the results of the experiment:

Angles of elevation.

Range	100 yards.	200 yards.	300 yards.	400 yards.	500 yards.	600 yards.	700 yards.	800 yards.	900 yards.	1,000 yards.
	′ ″	′ ″	′ ″	′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
Angles of elevation	14 22	26 40	39 2	54 3	1 11 3	1 30 53	1 52 5	2 12 40	2 36 31	3 0 14

---

* The range X and initial velocity V being given, the multiplier B, which is dependent on X, V, and "c", becomes known.

Having these discrepancies in mind, it occurred to me some time since to make use of the formula itself to deduce the value of the multiplier "B", and thence of "c" by substituting in it *known* conditions. These were the angles of elevation: φ, found by actual trial, the measured range X, and the initial velocity V, determined experimentally by the electro-ballistic, Le Boulengé, or other velocimeter.

The method is as follows:

We have, top of page 416, Ordnance and Gunnery, the equation

$$\tan \varphi = \frac{gX}{2V^2}B$$

in which

φ = angle of elevation;
X = range;
V = initial velocity; and
B = multiplier, dependent on $\frac{X}{c}$ and $\frac{V}{R}$[*];

whence,

$$\log \tan \varphi = \log g + \log X - \log 2 - 2 \log V + 10 + \log B$$

The angle of elevation of the service gun at 1,000 yards is 3°; the mean initial velocity is 1,335 feet, and the range, or X, is 3,000 feet; therefore we have

$$\log \tan 3^\circ = \log 32.16 + \log 3{,}000 - \log 2 - 2 \log 1{,}335 + 10 + \log B$$

or

$$\log B = .286951 \text{ and } B = 1.9273$$

But

$$\frac{V}{R} = \frac{1335}{1427} = .9355 \text{ and } \frac{X}{c} = \frac{3000}{c}$$

for a value of B=1.9273 from which to find c.

From table 1, page 510, Ordnance and Gunnery, we have:

$$B = 1.9273 = 1.863 + \frac{.028}{.05} - .0355 + \frac{.064}{.05}Y, \text{ whence } Y = .0347$$

But

$$\frac{X}{c} = .95 + Y = .95 + .0347 = .9847 \text{ and } c = \frac{3000}{.9847} = 3{,}046.7\text{[†]}$$

To apply this to determine the angle of elevation for a range, say of 500 yards, we have

$$\frac{V}{R} = \frac{1335}{1427} = .9355 \text{ and } \frac{X}{c} = \frac{1500}{3046.7} = .4923, \text{whence } B = 1.3899$$

$$\log \tan \varphi = \log 32.16 + \log 1{,}500 - \log 2 - 2 \log 1{,}335 + 10 + \log 1.3899$$

or

$$\log \tan \varphi = 8.274399 \text{ and } \varphi = 1^\circ\ 5'$$

Springfield pamphlet gives φ as 1° 11′.

For a range of 300 yards φ, obtained with the same value of c, is 33′ 50″.

Springfield pamphlet gives φ as 39′.

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[*] R is a constant, and is 1,427 feet.

[†] The method of course assumes the accuracy of the tables constructed by General Didion as applied to small-arms.

Assuming the angles given in the pamphlet as correct, and applying the method above explained for determining *c*, there results the following table:

Range	100 yds.	200 yds.	300 yds.	400 yds.	500 yds.	600 yds.	700 yds.	800 yds.	900 yds.	1,000 yds.
Value of "*c*"	457.3	1,105.8	1,771.8	2,117.5	2,338	2,441.7	2,564.4	2,757	2,867.1	3,046.7

If the angles are correct as assumed, this table shows conclusively that *c should change for every range.*

As the determination, experimentally, of the angles of elevation is a somewhat uncertain operation, caused by variation in cartridges, springing of the barrel, the sight, coarse or fine, taken by the marksmen, temperature, &c., the formula $t=\frac{X}{V}D$, page 415, Ordnance and Gunnery, for determining the times of flight of projectiles, may be employed. In this case the known conditions are the time of flight, the range, and the initial velocity.

By means of the Schultz chronoscope the time over a range of 1,000 yards or more may be accurately determined.

Owing to a lack of suitable conducting wires, necessary battery power, &c., this machine has not been used for this purpose at this armory.

The following times were, however, determined by means of a telephone and stop-watch:

Times of flight.

Range	700 yds.	800 yds.	900 yds.	1,000 yds.
Times of flight	2''.09	2''.563	3''.125	3''.606

This method of determination of the time is not supposed to be accurate, particularly at short ranges, but is sufficiently so at long ranges, because the error whatever it may be is the same, absolutely, for all, and is therefore proportionally less for the longer ones.

Applying the times in the formula above mentioned and working backward as before explained, there results the following values of "*c*" for the ranges given in the table:*

Range	700 yds.	800 yds.	900 yds.	1,000 yds.
Value of "*c*"	3,442	3,103	2,819	2,877

These values of "*c*," while differing from those deduced from the angles of elevation, show as before that "*c*" can only be considered as a constant for a particular range. But by the nature of its deduction by General Didion it is a constant for any further projectile, representing unity divided by twice the resistance on a unit of mass for a velocity of one foot per second.

The natural inference is, then, that Didion's method does not apply satisfactorily to rifled small-arms and their oblong projectiles.

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*These values of "*c*" indicate the probability of times being too great, a very slight variation in the latter causing a material variation in the former. The extreme sensitiveness of "*c*" to change is pointed out in the report of Captain Prince, before referred to.

APPENDIX 11.

INSTRUCTIONS FOR USE OF THE FRANKFORD ARSENAL HAND-TOOLS FOR RELOADING CARTRIDGES.

PREPARED BY MAJOR S. C. LYFORD, ORDNANCE DEPARTMENT.

(1 plate.)

This set of tools is designed for use with the Frankford Arsenal reloading cartridge shell, caliber .45, using either the 405 or 500-grain bullet, with 55 or 70 grains, respectively, of standard powder.

It is equally well adapted to the other re-loading shells in service having a central vent in their primer pocket.

NOMENCLATURE OF TOOLS.

The set of hand re-loading tools, model 1882, comprises the following-named parts:

1. Brush-wiper,
2. Charger, adjustable,
3. Die, reloading and crimping,
4. Die, re-sizing,
5. Drift,
6. Funnel,
7. Mallet,
8. Oil-cup,
9. Priming-tool (Frankford Arsenal),
10. Punch, re-loading,
11. Punch, re-sizing,
12. Safety-socket,
13. Shell scraper,
14. Washer, for re-loading punch.
15. Wiping-rod.

CARE AND PRESERVATION.

The tools should be used only for the purpose intended, with great care and regard to their preservation; with proper use they will last for many thousand rounds.

After use they should be cleaned, using the wiping-rod and clean oily rags, or cotton waste lubricated with cosmoline or paraffine oil, and kept in a dry place. *Never scour or polish them with any gritty substance.*

The re-sizing die is slightly smaller than the average rifle chamber. To prevent undue wear of its inner surface, the outer surface of the shell must be clean and slightly oiled before re-sizing.

Equal care should be exercised with the loading and crimping die. The slight contraction of its interior diameter, which does the crimping, can be very easily worn so as to render the die worthless for this purpose. The end surface of this die and the shoulder surface of the re-loading punch should be kept clean and free from the lubricant of the bullets, to insure, by their contact, the proper total length of the cartridge.

RE-LOADING OPERATIONS.

The order of operations is as follows:

Extract the primers, wash and wipe dry the shell, inspect the shell, lubricate the body slightly, keeping the interior head and the pocket free from grease; re-size, scrape out the burr from the mouth, prime (preferably by pressure), load, crimp, and lubricate.

SPECIAL PRECAUTIONS.

Inspect all shells and reject imperfect or doubtful ones. Re-size the shells after every round. *Never* attempt to *prime* a *loaded* shell. Before firing, lubricate the whole body of the shell with a suitable lubricant. The latter precaution tends to prolong the life of the shell in re-loading. When fired dry or only partially lubricated there is a tendency to early rupture of the shell; and the same effect may be due to too great a cartridge-head space in the arm, even when the shell and chamber are lubricated.

The conditions most fatal to the durability of the shell are a dry, clean chamber and shell, with the body of the latter near the head slightly lubricated. Under these conditions some shells will show signs of rupture on the first round.

CLEANING.

When water, preferably hot, is not available, the shell may be cleaned with the brush-wiper alone. Wipe clean, especially the exterior of the body.

INSPECTION.

Inspect for cracks near the mouth, a ring around the body near the head, longitudinal seams or other indications of weakness in the shell

RE-SIZING.

Lubricate slightly the exterior of the body only of the shell, force it into the larger end of the re-sizing die, using the mallet if necessary, striking the head squarely to avoid distorting the flange. When home, insert the punch in the mouth of the shell and drive it out of the die.

SCRAPING.

If the mouth of the shell is burred by the punch, insert the pointed end of the scraper, and holding the shell and scraper in separate hands, give each a half-turn in opposite directions, bearing only hard enough to take off the burr. The bifurcated end of the scraper is designed to remove any accumulation of powder residue from the interior annular space around the pocket.

PRIMING.

To set the tool for priming and to prime, turn the set-screw down to the shoulder, set the spindle with the pin end down, slip the shell over the spindle, place the primer on the pocket, push the spindle against the stop, and clamp till the primer is home in the pocket.

CHARGING.

The head of the shell is placed in the "loading" end of the safety-socket, the loading and crimping die slipped over it, and the funnel placed in the mouth of the die. The charger can readily be adjusted within one-grain limits. A steady uniform "dip" into a bowl of loose powder should be taken and no attempt made to settle it, the excess to be stroked off with a lead-pencil or other similar means. Pour the charge into the shell through the funnel, remove the latter, and slightly compress the charge in the shell with the wooden drift.

LOADING.

Insert the bullet in the mouth of the die and drive it home with the punch and mallet till the shoulder of the punch bears upon the end of the die. In loading with the 500-grain bullets the washer should be slipped over the punch before driving home.

CRIMPING.

Remove the punch, reverse the safety-socket, and place the die and cartridge in its "crimping" end; replace them on bench, and with the mallet strike the top of the die till its base bears upon the safety-socket.

LUBRICATION.

Before firing, grease the whole body of the cartridge shell with some suitable unguent.

GENERAL REMARKS.

Particular care should be taken that, after washing, neither oil nor water get into the shell, pocket, or primer.

In loading carbine cartridges five or six wads are inserted after the powder, to fill the space between the charge (55 grains) and bullet (405 grains).

The loading and crimping die will serve to gauge and inspect the finished work. If all cartridges enter it fully they will give no trouble in the chamber of the arm.

The provision of a separate tool for nearly every step in reloading permits the employment of several persons in the work, each performing a different operation and the shell passing from one to another until reloaded.

If properly used under the foregoing instructions, copper shells are good for at least ten, and in many cases fifty, rounds. They usually give timely warning of approaching rupture by the marks before described.

To adapt this set of reloading tools to use with the 2″.4 shell, a washer for the loading and crimping die will be supplied in addition. It is to be used in lengthening the die to accommodate the long-range shell. This same washer will serve the same purpose in connection with the socket and dies of Ordnance Notes No. 114. For the crimping-die of the latter set, a cap will be supplied when required, to accommodate the rifle-ball cartridges, model 1881, and 2″.4 shell. For the last-named shell a special resizing die will also be supplied when required.

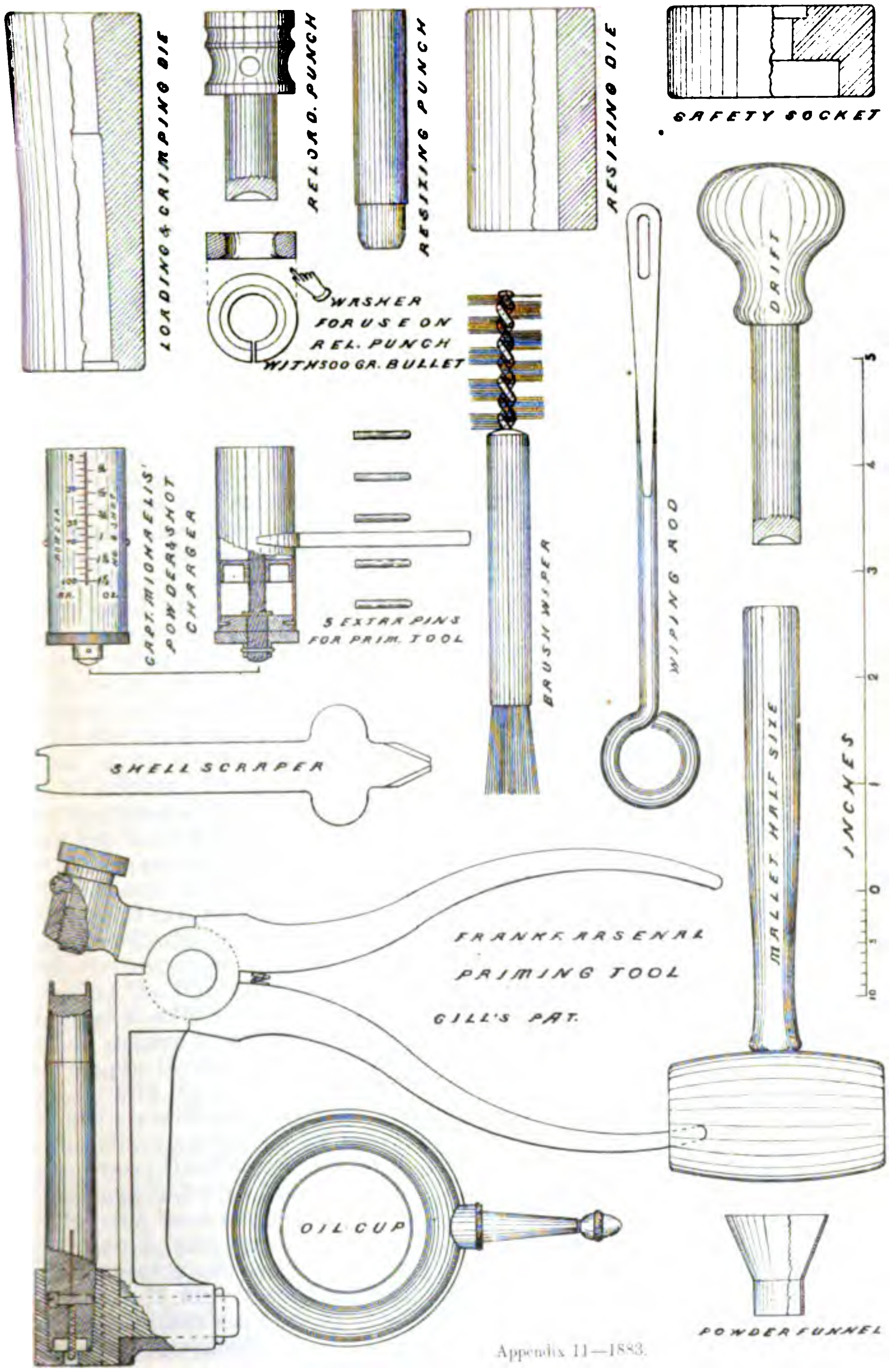
The annexed table shows the tools of both sets which practically correspond, and the additional tools necessary for either set to adapt them to the carbine and rifle cartridges.

Table showing what reloading tools of the sets described in Ordnance Notes Nos. 114 *and* 231 *are practically the same, and to what cartridges they are adapted either alone or with additional appliances.*

Nomenclature of tools as per Ordnance Notes No. 114.	Number of tool as per Ordnance Notes No. 231.	Tools adapted for carbine ball cartridges, model 1882.	Tools adapted for rifle ball cartridges, model 1881.	Tools adapted for long-range rifle ball cartridges, 2''.4 shell.
Brush-wiper	No. 1, same	Both	Both	Both.
Charger	No. 2, same; adjustable.	No. 2, Ordnance Notes No. 231.	Both	No, 2, Ordnance Notes No. 231.
Die, crimping Die, reloading	No. 3, same; in one piece.	Both	Both, except that the crimping-die, Ordnance Notes No. 114, requires a cap.	Ordnance Notes No. 114 requires a cap and washer for crimping-die, and the same washer for loading-die. No. 3, Ordnance Notes No. 231, requires the same washer.
Die, resizing	No. 4, same	Both	Both	Requires special long die.
Drift	No. 5, same	Both	Both	Both.
Extractor, primer	Represented by No. 9.	Both	Both	Both.
Funnel	No. 6, same	Both	Both	Both.
Mallet	No. 7, same	Both	Both	Both.
Oil-cup	No. 8, same	Both	Both	Both.
Priming tool, Bridgeport.	Represented by No. 9, for *inserting.*	No. 9, Ordnance Notes, No, 231.	No. 9, Ordnance Notes No. 231.	No. 9, Ordnance Notes No. 231.
Punch, primer	Represented by No. 9.	Both	Both	Both.
Punch, reloading die.	No. 10, same	Both	Both, with washer, No. 16 of Ordnance Notes No. 231.	Both, with washer, No. 16 of Ordnance Notes No. 231.
Punch, resizing die.	No. 11, same	Both	Both	Both.
Safety socket	No. 12; will not receive loading-die of Ordnance Notes No. 114.	Both, with respective dies.	Both, with respective dies and washer.	Both with respective dies and washer.
Scraper, shell	No. 13, same	Both	Both	Both.
Setter, primer	Represented by No. 9.	Both	Both	Both.
Wiping-rod	No. 15, same	Both	Both	Both.
	No. 16; washer for reloading punch.	Not required	No. 16, Ordnance Notes No. 231.	No. 16, Ordnance Notes No. 231.

Broken or disabled reloading tools will no longer be returned to Frankford Arsenal as required by the last paragraph of Ordnance Notes No. 114, but will be replaced by serviceable tools on the customary approved requisitions, as in the case of other ordnance stores.

PLATE I.


LOADING & CRIMPING DIE
RELOAD. PUNCH
RESIZING PUNCH
RESIZING DIE
SAFETY SOCKET
WASHER FOR USE ON REL. PUNCH WITH 500 GR. BULLET
DRIFT
WIPING ROD
BRUSH WIPER
CAPT. MICHAELIS' POWDER & SHOT CHARGER
5 EXTRA PINS FOR PRIM. TOOL
SHELL SCRAPER
INCHES
5
4
3
2
1
0
5
10
MALLET. HALF SIZE
FRANKF. ARSENAL PRIMING TOOL
GILL'S PAT.
OIL CUP
POWDER FUNNEL

APPENDIX 12.

REPORT ON RIFLE TARGET PRACTICE IN THE ARMY.

BY BREVET BRIGADIER-GENERAL JOHN C. TIDBALL, U. S. A.

WASHINGTON, D. C., *January* 29, 1883.

GENERAL: At your suggestion I have gone over the subject of target practice in the Army, and, tracing it up from the beginning, find that there was absolutely no provision for instructing the soldier in the use of his arm as a shooting weapon, or even mention of it as such, until 1854, when the rifle musket began to be introduced into the Army. Previous to this the smooth-bore had been the weapon for all arms of the service and was not entirely superseded by the rifle until 1856.

Compared with the rifle of to-day the smooth-bore musket was not much more efficient as a weapon of accuracy and range than a piece of gas-pipe closed at one end. It was, however, the weapon with which all the wars on this continent had been fought, down to that of the rebellion in 1861-'65. It is a remarkable fact that from the introduction of the flint-lock, in 1635, to that of the percussion-cap, about 1830—a period of 200 years—no improvement whatever was made in the firearm of infantry troops. The British fought at Waterloo with the same arm they used at Blenheim. More actual progress in perfecting military arms has been made within the last twenty years than was made in the 400 years preceding.

The smooth-bore musket was so inherently defective in point of precision as to call for no special skill in its use, and the term "no better than a soldier's gun" became a synonym for any inaccurate arm. Skill might be acquired in pitching quoits or hurling stones, but not so in directing the flight of the musket bullet. The marksman lost all control over it within certain but wide limits, after inserting it in his piece, and no degree of training could overcome the inaccuracy of its flight. The simple invention of an expanding bullet, enabling the rifle to be loaded with facility, caused that arm to supersede the smooth-bore musket for military purposes. In the United States service the change to the rifle commenced in 1854, at which time a printed circular was issued from the Headquarters of the Army for the government of the troop supplied with the new arm. The circular stated that the sights of the rifle were marked for ranges for each hundred yards from two up to seven, and that the practice should be at these distances. The circular recommended a certain proportion in which the cartridges should be used. It also recommended that the soldier should be taught to estimate distances, and by course of fine sighting to learn to fire at distances intermediate to those of the sight graduations. Specific instructions were given relative to loading, stating that, as there was no danger from excessive recoil, all of the powder from the cartridge should be poured into the piece, and the projectile inserted base downward, and that none of the paper of the cartridge should be put into the rifle. These are the first instructions anywhere to be found on the subject of target practice, and their curious minuteness testifies to the ignorance of the Army in this respect. But the circular, being only recommendatory, established no system, and left to each commander to execute as much target practice as he saw fit. The introduction of the rifle served to awaken, with some, an interest in target instruction, the offspring of which was another circular two years after the first, directing that—

> With a view to the improvement of the rank and file of the Army in firing with ball cartridges, the General-in-Chief proposes ordering a more general practice in this important branch of military instructions than is now provided for. This having become the more necessary by the introduction of long-range ammunition, and from the representation made to him of the lack of skill on the part of most of the men now in the ranks.

All officers were requested to communicate to him at an early day their views on this subject, and to state—

> Whether the practice should be weekly, monthly, or quarterly?
> What number of rounds per man should be allowed under ordinary circumstances at each practice?
> Under what regulations should the practice be conducted?
> What inducements to acquire skill should be held out? together with such further suggestions as their knowledge and experience may enable them to furnish.

A multitude of responses was made to this circular by officers of every rank and condition, a summary of which shows that at that period there existed in the Army but little knowledge of the subject of shooting, and that there was no systematic instruction whatever given in target exercises. All, however, evinced an eager desire to have a greater degree of instruction in this line, but none appeared to comprehend fully the subject or to be informed upon the requirements of a thorough system. With but one or two exceptions none proposed anything that could be called a system or indicated what should be done further than to have the guard fire off their pieces at a target upon being relieved, or occasionally to have company practice.

About this time Capt. Henry Heth, of the Tenth Infantry, published a manual for rifle firing, taken mainly from the book of instruction then in use at the School of Musketry at Hythe, England. Heth's manual supplied the deficiency theretofore so sorely felt. It was adopted as the authorized system, and being reprinted by the War Department at the outbreak of the rebellion, continued to be the standard until superseded by the Manual for Rifle Firing, compiled by Colonel Laidley, in 1879, and which is now the authorized text-book. In 1859, Cadmus M. Wilcox, lieutenant Seventh Infantry, published for the use of the American service an "Elementary Treatise on Rifles and Rifle Practice." He had recently visited Europe, where he had witnessed at schools of musketry the capabilities of the soldier to utilize the power of the improved arm. The object of his book was to endeavor to infuse into the United States service some of the spirit of progress witnessed by him in foreign armies.

Notwithstanding that the Army had now become armed entirely with an efficient rifle, and that a good system of target practice was available for its guidance, but little attention was given to it, and consequently but little progress made in instructing the troops in the use of the improved arm. This fact is well known to many who are now in service, and is a matter of official record, as appears from a General Order published from Headquarters of the Army in 1859, saying:

> As the reports of inspectors-general are evidence that the subject of bayonet exercise and target practice for small arms has been almost entirely neglected by the troops, especially the bayonet exercise, the General-in-Chief calls the attention of all officers concerned to the subject, and directs that hereafter the troops be regularly and systematically instructed in the full use of the several weapons placed in their hands.

Even with this spurring up there was but little progress made. There still appeared to be something lacking—some force wanting to give vitality to the desired movement. The trouble seems to have been that the Army was expected to take up the subject of rifle practice spontaneously, and without specific orders as to allowance of ammunition, time of practice, and method of making systematic reports. Officers, except those of most recent dates, had been brought up under the use of the smooth-bore musket, and, even after the new arm had been put in the hands of the troops, were slow to abandon the ideas imbibed from the old smooth-bore. In fact, the capabilities of the new rifle as to range and accuracy was entirely beyond comprehension, and it required time to discover its scope. Under similar circumstances the French made use of their schools of musketry as normal schools, at which instructors were educated to the new arm, and sent out into the army to extend the instruction throughout the whole. By this method but little time was required to introduce a uniform system and give proficiency to the entire service. The English at a later period imitated their example.

Prior to the outbreak of the rebellion in 1861 little or nothing had been done in the Army toward systematic instruction in rifle practice. Outside of the Army the elongated expanding projectile had not been to any great extent introduced. The old-fashioned Kentucky rifle and the fowling-piece were generally adhered to, and were the only arms familiar to the people. After the war commenced and huge armies were called into the field, but little attention, strange to say, was bestowed upon rifle instruction, and tens of thousands of men fired in battle their first shots with the Army rifle. Thus the value of the rifle as to accuracy was in a great degree lost for want of proper training to the soldier. Its great range was a matter of surprise to all, and to the "coffee coolers" in rear of the fighting line a matter of great annoyance.

After the suppression of the rebellion nothing continued to be done to insure rifle instruction until May, 1869, about a year after the troops had been armed with the breech-loader. At this date an order from Army Headquarters established a general system of target practice for the Army, and was the beginning of the system now in operation.

This order authorized the use of blank cartridges at discretion for the instruction of recruits, and to all troops ten ball-cartridges (since increased to twenty) per man per month for target practice; and what struck the key-note was, it directed that an officer at each post be designated to supervise target practice and make proper and systematic reports of the same. The text-book for instruction continued to be that of Heth, heretofore mentioned. Department commanders followed up this order by directing more specifically how it should be carried out. General Ord, then in command of the Department of California, directed target practice to be held at each post once a week, and report of it made to Department Headquarters, giving size of target, number of shots by each man, distance, and name of best and worst shot. The best shot to be excused from a tour of guard or fatigue duty after each practice-day, and the worst shot to be presented at company parade with a leather medal colored green. He became still more energetic in the matter of rifle firing, as appears from another order a few months later, in which, after specifying that only bakers, company cooks, and the sick were to be excused from weekly target practice, reports should be made to him of all other absentees. And again in 1875, when commanding the Department of Texas, he published an order enforcing target practice in that department, specifying how the ten cartridges per man per month should be expended, and reports made of the firing The new kind of target (Creedmoor) had not yet been introduced in the Army, and he specified that the value of the shots should be determined by string measurement, *i. e.*, by measuring from the center of each hit made by a marksman to the center of the bull's eye; these distances added together and divided by the number of shots fired by the man gave the value to the string. He directed that during continued bad weather simulated practice should be held in company quarters. He gave notice of his purpose to publish in the Army and Navy Journal the regiment and letter of the companies making the best monthly scores. He wound up his order by saying:

> The soldier is armed so that he may in battle hurt somebody with his rifle, and the sooner he learns to do so the better the soldier.

In September, 1877, General Ord, still in command of the Department of Texas, published an order adopting the Creedmoor target, describing its dimensions and construction, the manner of scoring the shots, the position of the marksman when firing at the different distances, and the method of signaling, &c. He introduced the custom of publishing monthly, in general orders, a recapitulation of target practice, showing the best and the worst shooting by regiments, by companies, and by individuals. December, 1878, he directed that the members of companies should be divided into two classes: the first to fire at 200 yards and the second at 100, and that no man should be advanced to the first until he had made in the preceding month's practice 60 per cent. of his possible score at that distance.

Some of the other department commanders were equally energetic, and target practice began to assume an air of business, but not of uniformity and system, throughout the Army; these latter objects were not effected until the issue of General Order No. 86 of 1879, from Headquarters of the Army. This order announced the "Course of Instruction in Rifle Firing," prepared by Colonel Laidley, of the Ordnance Department, as the approved system for the instruction of the Army in the use of the rifle. The same order directed that the Ordnance Department should provide the necessary targets, aiming-stands, &c., and prescribed that the labor and expense of setting up targets and preparing the shelters for marksmen, &c., should be born by the Quartermaster's Department. It also directed that "until there shall be provided by proper legislation a system of rewards, involving the expenditure of money, to encourage good marksmanship, department commanders will grant such indulgences to the best marksmen in their commands as they may think proper."

The course of instruction in target practice (that of Heth, published in 1857), theretofore the guide in the Army, had become obsolete. Laidley's book was a compilation agreeing in its general features with that in use by the National Rifle Association. Its adoption, therefore, brought the practice of the Army into accord with that of the rifle associations and volunteer organizations of this and other countries.

Another important feature of the order was, that it provided means by which its provisions could be carried out. Previous to it no administrative department had been charged with the duty of supplying targets and other necessary appliances to a rifle range, and this defect to a great degree paralyzed all attempts at carrying out a thorough course of instruction.

The system thus set in operation is uniform, causing all troops to go through the same course of instruction, using the same size targets, the same size bull's-eyes, centers, inners, and outers, and firing at the same distances. The points are registered on the same scale and forms; those scored by an individual or by a company are ascertained to a decimal, and reports made from posts to department headquarters, and thence to Army headquarters, so that at any time the firing capacity or figure of merit of an individual or of the entire Army can be ascertained.

The date of this order marks a new departure in the course of instruction given to the soldier, and, although of such recent date, it has produced results most gratifying.

The system has now been in operation three years. It required the first year to fairly organize operations, and the reports from departments show but few actual results: that from the East gives 75 qualified marksmen, from Missouri 14, Columbia and the South one each, while the remaining departments show not even one. The Engineer Battalion returns 34, making in all 124.

The reports of the second year show a great improvement over the first, and are as follows:

Department of Columbia, 33 companies, 1,663 men, returns 105 marksmen, and 214 of the first and 139 of the second class.

Department of Texas, 64 companies, 3,266 men, returns 66 marksmen, and 66 of the first and 109 of the second class.

Department of Dakota, 94 companies, 3,820 men, returns 81 marksmen, and 115 of the first and 140 of the second class.

Department of California, 18 companies, 763 men, returns 72 marksmen, and 70 of the first and 67 of the second class.

Department of the East, 41 companies, 1,009 men, returns 95 marksmen, and 66 of the first and 51 of the second class.

Department of the Platte, 54 companies, 2,228 men, returns 20 marksmen, and 71 of the first and 193 of the second class.

Department of the Missouri, 84 companies, 3,427 men, returns 70 marksmen, and 63 of the first and 64 of the second class.

Engineer Battalion, 3 companies, 129 men, returns 62 marksmen, and 15 of the first and 8 of the second class, making for the entire Army 391 companies, 16,305 men, a total of 571 marksmen, and 680 of the first and 771 of the second class.

The troops of the Department of Arizona, consisting of 24 companies, 1,213 men, were engaged in active operations against hostile Indians, and no return was made from it.

The return from the Department of the South, consisting of 13 companies, 481 men, was so defective as to be unintelligible, and is therefore omitted. The omission, however, does not materially affect the foregoing total, because it seems that but little attention was given to the subject in this department.

The practice of the Engineer company stationed at West Point was interrupted in consequence of its range being destroyed by the construction of a railroad. It is, therefore, not included in the return for the Engineer Battalion.

The foregoing figures signify that in the Army there were in October of last year 571 men—marksmen—capable of using the rifle to its utmost capacity, and, in addition, 680 who were good and 771 who were fair shots. These figures also show that the system is in full operation, and it may confidently be expected that the returns of the present year will show a ten-fold progress. Indeed, the returns already published from the Headquarters of Departments show that such will be the case.

At many posts, notably those of the artillery regiments, it is impracticable to obtain sufficient length of range to qualify riflemen as marksmen. That certain troops are so situated, reduces very considerably the figure of merit for the department in which they are stationed. As an entire organization, the Battalion of Engineers is far ahead of all others in marksmanship. This command, stationed at Willets Point, convenient to Creedmoor, enjoys the advantages of that admirably equipped range—thus giving evidence of the benefit to be derived from such facilities. In this connection it may be mentioned with regret that the estimate for target practice for the present fiscal year was cut down from $180,000 to $25,000, the sum appropriated by Congress.

An examination of the returns from the several departments discloses the great superiority of some regiments over others. There is also that diversity among companies of the same regiment, and it is particularly marked as to different posts. A careful scrutiny of the returns shows that this difference is not due to inequality in the enlisted material of different commands, but that a greater interest and stricter attention have been bestowed by some regiments, posts, and companies than by others to target practice. The concentration into a few companies or posts of the best shots in a department shows that a more careful supervision over the duty of rifle instruction would greatly increase the figure of merit for the department. The military service is not so much benefited by the special excellence of a few men as by a general diffusion of a good average. It is observed that a great difference also exists between departments, a good deal of which is due, no doubt, to the nature of the service required of each. But there are some of the foregoing differences that cannot be satisfactorily explained, as for instance: In the Department of the East, one company, Lancaster's, Third Artillery, numbering 33 men, had 19 marksmen, or nearly 60 per cent. of its strength. Several other artillery companies in the same department closely approximated to this, and quite a number more showed a good figure of merit, while, on the other hand, the Tenth Infantry, stationed at permanent and comfortable posts on the Lakes, and situated similarly to the artillery companies, but unincumbered with artillery duties, produced out of the entire 10 companies only one marksman.

In this connection the following remarks of General Terry, commanding Department of Dakota, commenting in a general order upon the inequality of rifle instruction in different commands, are apropos:

> No one can doubt that the average capacity of the men to learn how to use their arms effectively is the same in all companies and at all posts. Nearly all the men enter the service without previous experience in the use of arms, and the number of those in any organization who have had previous experience is too small to affect its character; moreover, the experience of that small number is seldom such as to be of value in the prescribed course of rifle instruction. It cannot be supposed that there are any essential differences in the averages of either physical or mental qualification in the different parts into which the Army is divided. This being the case, the different results obtained in different organizations must be due to the officers who command them, and to the officers alone. Where officers are obedient and carry out in good faith the orders which prescribe the course of rifle practice; where they are intelligent and zealous; where they not only demand obedience from their men, but seek to awaken their interest in this, the most important part of their instruction,

and especially where they endeavor to excite emulation by practicing with their men and by becoming good shots themselves, excellent results will assuredly follow.

But when officers are disobedient and fail to carry out with precision the orders of their superiors; when they are indifferent and lukewarm; when the instruction which it is their duty to give, if given at all, is given in a mechanical and perfunctory manner, without warmth or interest, their men will as assuredly fail to learn the use of their arms, and under existing conditions of warfare they will be nearly worthless as soldiers.

In these days of arms of precision and with the tactics which these arms have made necessary, the man who has not been taught to attain his mark with reasonable frequency, at distances much greater than one or two hundred yards, is an incumbrance rather than a helper on the battle-field.

Moreover, offensive power in action is defensive power also. Indeed, there is no other defensive power except, perhaps, the power to run away, and, inasmuch as the department commander is sure that there is no officer in the department who would contemplate that method of preserving the lives of his men, he is forced to the conclusion that those who habitually and persistently neglect the instruction of their men in the use of the rifle are thoughtless of—he trusts that they are not wholly indifferent to—the great responsibility which rests on those in whose hands the lives of men are placed.

The department commander is aware that for the neglect of a few officers some palliation may be found in the fact that their men have been busily employed during the past summer as mechanics and laborers, in building and repairing barracks, quarters, &c. This fact, however, is only a palliation, it is not a justification, or at least it is not a justification for the commanders of the posts where the men have been so employed. It may be a justification for the company officers at such posts.

The building and repairing of barracks and quarters is a necessity, and unfortunately the work must, to a great extent, be done by the labor of troops. But the instruction of the men in the use of their arms is a greater necessity—it is the paramount necessity, and it must not be neglected in favor of any work whatever. It is sometimes urged, as an excuse for failures to have target practice, that troops have been in the field; but this is no excuse at all. Of course, when troops are making long marches in an active campaign there is little or no time for instruction; this is the time when the fruits of former instruction should show themselves; but no field duties have been imposed on any troops in the department during the past year which should have prevented target practice from being carried on with tolerable regularity. Targets can be improvised and practice can be had everywhere in the open country. Indeed, practice, under the conditions which exist in the field, may often be a very valuable variation on the practice which takes place on the ranges established at posts. Some of the troops which were in the field during the last summer and autumn did keep up their practice and did attain results which, to say the least, were not discreditable.

To avoid, in the future, all questions upon these points, the department commander now *directs* that hereafter no work of any kind, no matter how important it may be, no absence from stations, shall be suffered to prevent the regular and complete instruction of the men in the use of the rifle, or to prevent their having that amount of practice which is requisite to make their fire effective.

The following figures, taken from the annual reports of musketry of the various departments, represent the results of rifle practice for the target year ending September 30, 1882:

Department of Columbia, 31 companies, 1,411 men, returns 197 marksmen, and 118 of the first and 112 of the second class.

Department of Texas, 52 companies, 2,870 men, returns 146 marksmen, and 70 of the first and 92 of the second class.

Department of Dakota, 102 companies, 4,009 men, returns 427 marksmen, and 237 of the first and 434 of the second class.

Department of the South, 13 companies, 454 men, returns 86 marksmen, and 28 of the first and 42 of the second class.

Department of California, 20 companies, 930 men, returns 198 marksmen, and 87 of the first and 78 of the second class.

Department of the East, 52 companies, 2,115 men, returns 103 marksmen, and 133 of the first and 97 of the second class.

Department of the Platte, 42 companies, 1,819 men, returns 223 marksmen, and 108 of the first and 165 of the second class.

Department of the Missouri, 88 companies, 4,213 men, returns 261 marksmen, and 190 of the first and 192 of the second class.

Department of Arizona, 33 companies, 1,679 men, returns 35 marksmen, and 34 of the first and 77 of the second class.

Battalion of Engineers, 3 companies, 163 men, returns 61 marksmen, and 8 of the first and 1 of the second class—making in all 1,737 marksmen, and 1,013 of the first and 1,290 of the second class, out of a firing force of 19,613 men, a showing certainly not discreditable to any army.

A comparison of these results with those of the previous year shows a very considerable progress, and indicates a growing interest in rifle instruction. The reports furthermore show a great increase of percentage of men undergoing such instructions over that of former years. Field operations against hostile Indians in the Department of Arizona have continued to interfere with target practice in that department, but a glance at the figures will show that considerable progress has been made notwithstanding such interference. Outside of Arizona there is but one other post in the entire Army (Fort McIntosh, Texas) where firing instruction has been wholly omitted. At some of the posts in the Department of the East there is not available space to admit of 600 yards' ranges; consequently, at such posts, riflemen cannot qualify as *marksmen*, and are compelled to continue in the *first class*, although they may possess the highest skill in the use of the rifle. In all the other departments the reports show that good range facilities generally exist, and are becoming well equipped with butts, targets, and other necessary appurtenances. Facilities for indoor practice are not so good, arising from want of appropriate buildings at posts. The troops are thus to a great extent deprived of this very important part of rifle instruction. The best authorities upon the subject attach greater weight to such instruction than to actual firing.

Implements for reloading cartridge shells, supplied by the Ordnance Department, are becoming generally distributed to all posts and companies, thus affording the soldier the opportunity of supplementing the authorized allowance of prepared ammunition by as much prepared by himself as he can reasonably desire. The Ordnance Department supplies targets. The pattern found most suitable is the one copied from those in use at the Brinton Range in New Jersey, and known in the Army as the Brinton target. This target works up and down after the manner of window sashes, except, moving simultaneously, one goes up while the other is coming down.

Accompanying the annual reports are numerous recommendations, all suggested by experience, and looking in the direction of increased efficiency, progress, and system.

One of the best features of the present target system is that officers are required to practice with their men. This is important, insuring to the officer as well as to his men a thorough practical knowledge of the use and capabilities of the weapon with which they are armed. It also brings the officer into an official relationship with his men that teaches him patience and perseverance while instructing, and forbearance in the exercise of arbitrary authority.

Systematic rifle firing has not been in vogue long enough in the Army to have demonstrated for it any marked influence on Indian campaigning. It has so happened that the regiments most actively engaged in such operations have had the least opportunity for target instruction. Reports of the recent hostile operations in Arizona make mention of the superiority of firing by some of the troops engaged, and attribute it to the advantages derived from persistent target practice.

The circle of such influence must necessarily widen, and in time all troops engaged against Indians will give the same good reports. A fair percentage of marksmen in the command of Custer would doubtlessly have averted the massacre of the Little Big Horn.

Considering that target practice to any extent in the Army is of such recent date that instructors had to be created and a system devised and set in operation, the present degree of progress may be looked upon as very encouraging; this, too, in the face of unusual obstacles arising from the peculiar nature of our service, the dispersed condition of troops, and in no small degree to the conservatism of old ideas, fostering the habit in time of peace of looking upon the soldier's rifle as anything else than a shooting weapon.

Provision for the instruction of mounted troops in firing practice has been made by General Order No. 57 of May last, which prescribes a systematic course of exercises with both pistol and carbine, mounted and dismounted. The system of instruction is the same as that in use by the infantry, with only such modifications as may be necessary. No provision had ever before existed in our service for regular and systematic instruction in firing by mounted troops, and it is expected that as much progress will be made at mounted firing as has been made at rifle practice by foot troops. When the system is sufficiently developed a percentage will be established for classification in mounted practice.

RIFLE CONTESTS AND COMPETITIONS.

The system of competitive rifle firing inaugurated for the Army by General Order No. 44 of last year is a natural outgrowth of the system of target practice just described.

In all marksmanship there appears to be an inherent quality that creates in those practicing it a desire for competition and contests. This we perceive in the history of shooting from the earliest days of archery to the present epoch of rifle associations. Contemporaneously with the establishment of Creedmoor a spirit in favor of rifle practice developed itself in the Army and produced some excellent marksmen. In several of the contests at Creedmoor, Army teams were eminently successful, showing that even under unfavorable circumstances for instruction such teams were able to hold their own in competition with the best shooting skill of the country. These successes created a desire for more, but it was found impracticable to continue the practice of sending teams to Creedmoor. It was deemed more advantageous to the service to utilize this eagerness for competitions by making it the means of a general diffusion of interest in target practice throughout the Army.

The theory upon which the present system of competitions is founded encourages individual excellence among all classes in the Army, in contradistinction to forming teams of special merit from a few upon whom all the instruction is bestowed. To this end three grades of contests have been provided for, viz, the department, the division, and the Army contests. In the first of these each company in a department is represented by its best qualified marksman. This annually brings together the best material of each department, who, entering into a series of contests for places on a team of twelve to represent the department in the division contests, mutually instruct each other by association and observation. These men returning to their respective companies impart to their comrades the instruction thus acquired. The results aimed at by this system are, in a degree, similar to those accomplished by the British at their school of musketry at Hythe and by the French at theirs of Vincennes. To the former of these schools officers and selected enlisted men are sent; to the latter only officers. They there undergo a course of rifle training, and returning to their commands, themselves become instructors. These institutions are therefore simply normal schools for the training of teachers in rifle practice. The department annual meetings of our system operate to the same end, and although the system has been in operation but two years, it has given evidence of entire success; probably as much so as either that of the English or the French.

The scheme is further extended by annually assembling the department twelves to compete for the honor of places on a division team of twelve. Finally, every two years each military division is represented, in proportion to its numerical strength, by its best shots, in a team of twelve to compete for the championship of the Army. The system thus embraces the enlisted men and officers of every company in the service, giving to each an equal chance for the winner's place.

For each of these contests appropriate prizes are awarded the successful competitors, viz, 1 gold medal for each department; 4 gold and 8 silver medals for each division—in all 21 gold and 24 silver medals annually, to which every two years are added 3 gold and 3 silver medals for the winners in the Army contest. An unavoidable delay occurred last year in preparing the prizes, and it was not until late in the present year that they were distributed. Such delay will probably not again happen.

Careful note was made of every real or supposed defect in the system during its first year's operation, all of which were eliminated, as far as possible, in an amended order. It was, however, found that no material change was necessary; that the original order contained all necessary elements of a good system. The following are the provisions of this order:

I. At every military post the commanding officer will enforce existing orders and regulations on the subject of target practice, and, whenever practicable, will encourage officers and men to hunt for game, for which suitable ammunition will be furnished by the Ordnance Department.

II. There will be three grades for competition and Army prizes:

1st. The Department.

2d. The Division.

3d. The Army.

III. From the reports of the best target firing at posts and camps, and from such other data as may be available, the department commander will, annually, cause a selection to be made of the most suitable "marksman" of each company, troop, or battery, and one from each non-commissioned staff or band. The officers and men thus selected will be assembled at some convenient post of his command, in the month of August of each year, to compete for places in the department team of twelve. In these competitions the distance will be two hundred yards standing, three hundred yards kneeling, and six hundred yards lying in any position within the rules. After such amount of preliminary practice at the rendezvous as the department commander may prescribe, the competitions will take place and will extend through three days. On each of these days (not necessarily consecutive) every competitor will fire one complete score of seven shots at each of the prescribed ranges, and a report thereof will be transmitted to the division commander for his information. The twelve marksmen making the highest aggregate scores in these competitions will constitute the department team of twelve, and to that marksman making the best aggregate score will be awarded a suitably inscribed gold medal. Two alternates may be added to the team, at the discretion of the department commander. In assembling the competitors, no ordinary exigency of the service, field or other duty will be allowed to interfere with the representation of every company having a qualified marksman; and commanding officers will forward to the place of competition the descriptive lists of enlisted men, and the qualifying scores, with dates, of *all* marksmen selected for the competitions.

IV. The division commander will assemble the several department teams of twelve, at some convenient post in his division, to compete early in September in like manner for the honor of places upon the division team of twelve and for the prizes herein described: First prize, a suitably inscribed gold medal; to the next three, a suitably inscribed gold medal; and to the remaining eight winning competitors, each a silver medal. In these competitions the firing will be *individual*, by the collective members of all the department twelves, and will not be regarded as a contest of teams, as units, against each other.

V. Finally, every alternate year, beginning in 1882, the General of the Army will assemble, from the entire Army, twelve of the best shots to compete for the Army prizes. The number to be furnished from each military division and from the Engineer Battalion, together with the time, place, terms of competition, name of director, &c., will be announced in orders. The first prize will be a gold medal, suitably inscribed; the next two, each a gold medal; and the next three, each a silver medal. All prizes herein set forth will be prepared by the Ordnance Department, the expense attending their preparation to be paid for out of the contingent fund of the Army, and become the absolute property of the winners. The medals may be worn on all dress occasions.

VI. In all the foregoing competitions only the service rifle and service ammunition, as issued to the troops, will be used. The aiming notch of the rear-sight slide may be slightly opened or widened, if desired, to accommodate age or individual peculiarities of eyesight, but no other filing or alteration of the regular service sight, as issued by the Ordnance Department, will be permitted.

VII. The marksman's rifle will no longer be issued as contemplated in paragraph 524, revised edition, Laidley's Rifle Firing. Marksman's buttons, in pairs, will be issued heretofore as prescribed, and will remain the property of the marksman.

VIII. The Ordnance Department will issue from time to time long-range rifles for experimental purposes. These are adapted to a different kind of ammunition, and must not be confounded, in the execution of the foregoing general orders, with the "service rifle" and the "marksman's rifle" (herein referred to), these two having the same caliber and using the same ammunition—the last distinguished by its different form, greater cost, and superior sights.

IX. Ordinary signaling being inconvenient during these competitions, a sufficient number of telephones will be furnished for the ranges by the Signal Corps, and the Quartermaster's Department will supply all the necessary materials for constructing butts, firing-stands, &c.

X. As a further means of cultivating the individuality of marksmen, skirmish matches may also be conducted at the annual contests, under the orders of the department and division commanders. "Team" firing being useful as giving valuable lessons when a united body of men are required to work together, in action, for a specific purpose, the department teams of twelve, after the conclusion of the regular division contests, may be permitted to compete, as organized units, against each other, under the orders of the division commanders; and, in their discretion, division commanders may also arrange matches over longer ranges, in which the use of the marksman's rifle and the Springfield long-range rifle may be permitted, together with the special and experimental ammunition on hand for use. For all the foregoing contests the Ordnance Department will issue the necessary arms and ammunition upon duly approved requisitions.

XI. Hereafter, in the regular monthly target practice, not more than fifteen shots will be fired by any man, on any day, at any one distance. A score will consist of not *less* than five consecutive shots, but the score must not be computed by selecting *any* five consecutive shots out of the whole number fired by the man at the same time and distance; they must be divided regularly, as the first five, second five, &c.

GENERAL RULES FOR COMPETITORS AT THE PRESCRIBED DEPARTMENT AND DIVISION CONTESTS.

Immediately before the commencement of the contests the duly authorized competitors will, by lot, be assigned targets and order of firing. Each will be furnished with score-cards, upon which his number, distance, day, hour, and target will be entered. No application on the part of a competitor, for any alteration in his lot thus determined, will be entertained. No "alternate" will be allowed to compete in the place of any marksman, unless the latter be unable, by sickness, to be present, which fact, when practicable, must be duly set forth by a surgeon's certificate.

The competition will commence at two hundred yards, each competitor firing at the target and in the order stated on his score-card, the odd number of each pair taking his place on the right, at the firing point, and firing first; the pair firing alternately until each man has finished his score at that distance. Firing will be continued in a similar manner at three hundred and six hundred yards.

No sighting shots will be allowed in any competition, but targets will be assigned, at which competitors may practice at any time, provided such practice does not interfere with their presence at the designated time at the firing point to which they may have been assigned.

Rifles may be cleaned only between scores.

If practicable, commissioned officers will act as scorers, and will take their places at the firing point directly in rear of the men firing. Spectators and others, not competitors, will not be permitted to hold any communication with the scorers. All competitors, when not firing, will take their places in rear of their respective firing points, at a distance designated by the officer in charge of the competition.

At the competitions for Army prizes no "coaching" or unnecessary communication of any kind with those actually firing will be allowed.

Competitors will wear the prescribed fatigue dress, with belt, of their grade in the Army.

Skirmishers' competitions by division and department teams, when restricted to the service rifle, should be confined to ranges from six hundred to two hundred yards and to target "B."

Skirmish competitions—in which the Springfield long-range rifles, authorized in paragraph 8, may be used with any ammunition—will be encouraged, and should extend to ranges of eight hundred, nine hundred, and one thousand yards.

Skirmishers are not restricted as to position in firing at any distance.

Skirmish competitions or matches between *organized teams* partake necessarily of the individual character, and in order to insure strict fairness and equal conditions for all, the several lines maneuvered should be composed of equal numbers from each team competing, and the firing be continued until all have fired.

The director or officer in charge, accompanied by a trumpeter, maneuvers the line as in his discretion may seem best, in quick or double time, forward or retiring, using at all times the tactical commands, and allowing such time for halts and firings as he may judge best calculated to make the exercises as nearly as possible resemble actual skirmishing in front of the enemy, care being taken that no competitor has sufficient time to fire his twenty shots before retiring from the firing point nearest the target.

File-closers, to repeat commands, report irregularities, &c., will, when required, be designated by the director.

Competitors in skirmish contests (not more than three at any one target) are formed in line at the six hundred yards' firing points, with twenty cartridges each, in boxes or belts, and at the command or signal "*Skirmishers*, ATTENTION," load their rifles. At the command or signal "*Forward*, MARCH," the line advances until the signal "*Skirmishers*, HALT," when the sights are adjusted to the estimated distances. At the command "*Commence* FIRING," each competitor fires at least one shot. *This rule is general.* Firing ceases at the command "*Cease* FIRING," after which no competitor fires until the command "*Commence* FIRING" is again given.

Having approached sufficiently near the two hundred yards' firing point, the signal "*To the rear*, MARCH," is given, when the maneuvering to the rear and firing will continue until twenty shots per man have been fired. The rifles are carried on the right shoulder when maneuvering to the rear.

The number of halts made in advancing and retiring are determined by the director, and must not be announced to competitors.

Upon returning to the six hundred yards' firing point, the signal "*Cease* FIRING" is sounded, and repeated *twice*, when the markers examine the targets and signal the total hits upon each, as follows: 1st, bull's-eyes; 2d, centers; 3d, inners; and 4th, outers.

PENALTIES.

Five points will be deducted for each failure to fire at least one shot at each signal "commence firing" (unless his twenty shots shall have been already expended by the competitor); for each shot fired after the signal "cease firing," and for each shot in excess found to have hit any target.

Competitors firing on the wrong target may, in the discretion of the officer in charge, be debarred from further competitions.

The department, division, and Army contests of this year were of unusual interest, and were conducted in strict conformity with the foregoing. The department contests took place on ranges at the respective Department Headquarters, with the exception of that for the Department of the East, which was held on that of the National Rifle Association, at Creedmoor, L. I.

The following were the number of contestants assembled at each:

Department of the East, 31 enlisted men and 6 officers	37
Department of Texas, 50 enlisted men and 3 officers	53
Department of Arizona, 17 enlisted men	17
Department of Missouri, 43 enlisted men and 9 officers	52
Department of Dakota, 47 enlisted men and 5 officers	52
Department of the South, 8 enlisted men and 2 officers	10
epartment of the Platte, 30 enlisted men and 2 officers	32

From which it is seen that a fair percentage of commissioned officers are represented in these contests, a fact worthy of note as showing that interest in rifle-firing is taking hold where it is likely to do most good.

The first competition for Army prizes took place this year. The contest was held on the 25th, 26th, and 27th of October last, at Fort Leavenworth, upon a range prepared during the summer for the contests of the Division of the Missouri. The team in this contest consisted of twelve marksmen selected as follows: Two from the Division of the Atlantic; three from the Division of the Pacific; six from the Division of the Missouri, and one from the Battalion of Engineers. These numbers represent, as nearly as practicable, the relative strength of the organizations named; and the marksmen from each, having won their places on the team by success in the department and division contests, may fairly be considered as representing the best firing skill of the entire Army. The arm used was the regulation Springfield rifle, in which no alteration whatever was allowed. The minimum trigger pull was six pounds, a test of which was made previous to firing at each range. The ammunition was the service cartridge—70 grs. powder and 405 grs. bullet—issued to the contestants from boxes taken at random from the store on hand in the magazine, and freshly opened on the range. The arm and ammunition was therefore absolutely that of service as issued to the soldier for his use in the field.

The distances were 200, 300, and 600 yards; at the first, the position of the marksman was standing; at the second, kneeling; and at the third, lying in any position within the rules for rifle-firing. Eight of the contestants took the prone position with head to the target, and four the back position with feet towards the target. The target for the 200 and 300 yards' ranges was the "A," or third class, and that for the 600 yards' range the "B," or second-class target. Three of each were used for each range. The contestants were divided by lot into two *reliefs*, thus giving pairs of twos for firing at the same time at each target. The assignment to targets was made by lot, thus securing entire fairness so far as any preference of position was concerned. Each contestant fired seven shots at each range on each of the three days, making in all sixty-three shots. The marking at the targets and the score keeping was performed by officers detailed from the garrison for the purpose; in short nothing was omitted to insure absolute fairness throughout. All were familiar with the rules governing such matches; no points were raised calling for decision, and everything worked harmoniously. The firing began each day punctually at 9.30 a. m., commencing with the 200 yards' range, next the 300, and finishing at the 600 yards' range. The range was in good order, the weather unexceptionally fine, and every arrangement for the contest complete and satisfactory. The contest was witnessed by the General and Lieutenant-General of the Army and by many others, all of whom evinced the deepest interest in the firing.

As soon as practicable after the conclusion of the contest the troops of the garrison were paraded and the following order announcing the result of the contest read:

HEADQUARTERS OF THE ARMY,
Fort Leavenworth, Kans., October 27, 1882.

The competition directed in General Orders No. 54, current series, Headquarters of the Army, Adjutant-General's Office, having been conducted and completed in conformity with the rules prescribed in General Orders No. 53, same series, the following-named members of the Army team, having made the highest scores, are announced as the winners of the prizes prescribed in paragraph five of the last-named order:

First prize.—Sergeant *Charles Barrett*, Company B, Battalion of Engineers.

Second prize.—Sergeant *Cyrus H. Clark*, Troop B, First Cavalry.

Third prize.—Sergeant *Albert W. James*, Troop B, Eighth Cavalry.
Fourth prize.—Sergeant *Joseph Daly*, Battery G, First Artillery.
Fifth prize.—Private *Alphonso Harrington*, Battery C, First Artillery.
Sixth prize.—First Lieut. *William B. Homer*, Fifth Artillery.

The General having in person attended the contest through three days, and having borne personal testimony to the fairness of this manly contest for excellency in marksmanship, takes great pleasure in personally bestowing the prizes fixed in general orders, viz: Gold prizes, with suitable inscriptions, to the three first named, and silver prizes to the last three; and he further directs that this order be read at dress parade of every garrison in the United States.

W. T. SHERMAN,
General.

After which, in the presence of the battalion and a large concourse of civilian spectators, the General presented to each of the winners the medal so honorably won by him.

These department, division, and Army contests are agreeable and exciting episodes in a soldier's military life, and full of excellent experiences, acquired by observation and mingling together of the best shots in the various departments, and afterwards disseminated through the company to which each individual belongs, creating an interest in rifle practice which can be given in no other way.

It is remarked that the prize winners in these contests are known throughout their regiments as men of irreproachable character, remarkable for their strength, activity, and endurance—the prime qualities of the soldier—and for that evenness of temper and self-possession which is the result of correct physical training. It is furthermore remarked that those commands standing highest in rifle practice (where all have had equal opportunities) are those bearing the highest reputation in other soldierly qualities.

The only serious drawback to the working of the system of contests is the personal expense entailed upon the participants in attending the places of contest. This, in many cases, is onerous, and is well known to be so; but at present there seems to be no way of alleviation. It is hoped, however, that some means may hereafter be devised to that end.

The badge known as the Nevada Trophy, described in General Order No. 45, of last year, was awarded to Capt. Lewis Smith's Battery K, Third Artillery, it having given evidence of having made the best score of any troop, company, or battery in the Army during any month of the target year 1880–'81. Nothwithstanding the score was extraordinary, several companies were close up to it, showing that the contest had excited deep interest.

MILITARY TARGET PRACTICE IN GENERAL.

The movement in favor of rifle shooting, which for the last few years has pervaded all classes of military organizations in this and other countries, is by no means a new thing in target practice, but is a repetition of customs extending back to older times.

Before the introduction of fire-arms, when the bow was the shooting weapon of armies, the greatest possible attention was given to the instruction of the soldier in its use. So far back as 1530, during the reign of Henry VIII, a law was enacted, the preamble of which sets forth that—

> The King, our Sovereign Lord, calling to his most noble and gracious remembrance that by the feats and exercise of the subjects of his realm in shooting with the long bow, there hath continually grown and been within the same a great number and multitude of good archers, which have not only defended this realm, and the subjects thereof, against the cruel malice and danger of their outward enemies in time heretofore past, but also with little numbers and puissance, have done many other, &c.

The law prescribed in the most minute manner the means by which instruction should be given. From this date on down are to be found in military history traces of like provisions for target instruction.

Upon the introduction of fire-arms, the musket had a long and hard struggle to supplant the bow. It was a contest of two hundred and fifty years. The bow had a range up to 400 yards, greater, in fact, than that of the musket, was much less expensive, could be discharged with greater rapidity, and was more easily carried by the soldier. A distinguished military writer in 1580 said of the musket: "Except the noise in our ears, to which we will henceforth be accustomed, I think that it is an arm of very little effect, and I hope that we shall one day give up its use." The invention of the flint-lock, in 1635, added greatly to the efficiency of the musket, and decided the contest in its favor. The change from the bow to the musket was prejudicial to the personal skill of the soldier, for the new arm had defects of accuracy which no skill could overcome, and he therefore lost that confidence which he had previously felt in his own expertness in using the bow. No longer measuring strength in encounters in which each could attest his individual skill, men had ceased to be marksmen when equipped with no better weapon than the inaccurate smooth-bore. There was a long interval in which target practice received but little attention, and so far as can now be ascertained no systematic measures for the improvement of the fire of soldiers were undertaken until in 1860 the French, then at war with Abd-el-Kader, in Algeria, discovered that the Arabs, armed with their long and uncouth-looking guns, were far their superiors in marksmanship. To overcome this disadvantage they established schools of musketry at Grenoble, St. Omer, Toulouse, and Vincennes, and soon discovering that the defects of the smooth-bore as to accuracy of fire were incurable, they instituted a series of experiments with a view to making the rifle a suitable arm for military purposes. This required that the rapidity of fire of the smooth-bore should not be sacrificed. The problem, therefore, was to discover means by which the rifle could be loaded with a projectile that, entering the bore freely, would leave it with such tightness as to cause it to take the grooves of the piece. Various devices were introduced to effect this, all using the spherical bullet and expanding it in the bottom of the bore by mechanical means. None of these, however, proved satisfactory, until Captain Minié, as late as 1847, produced an elongated projectile, the base of which was hollowed to receive an iron cup which, being forced into the cavity by the gas of the explosion, expanded the bullet into the grooves. This arm was immediately adopted by the French and other nations.

During a series of experiments at Harper's Ferry, extending through 1853 and 1854, to determine the best form of rifle for military purposes, Mr. Burton, the assistant master armorer, discovered that the iron cup of Minié and all other similar devices, more or less complicated and objectionable, could be dispensed with by simply hollowing out the base of the projectile and permitting the gas from the explosion to expand the bullet by direct action. This simple device was a solution of the whole problem. It permitted the projectile to enter the bore loosely and by the discharge it was expanded to take the grooves. Simultaneously with Burton's discovery, but without knowledge of it, Mr. Pritchell, gunsmith, of London, made the same discovery. The rifle was at once adopted in all countries as the military arm.

The English, in 1853, followed the example of the French by establishing schools of musketry at Hythe and Fleetwood. Schools for like purposes were about the same time established by other European nations. Soon afterwards volunteer organizations took up the subject and rapidly developed the methods and rules now in vogue at rifle ranges. Wimbledon was established in 1860, Creedmoor in 1873. The time and manner of the introduction of rifle instruction in the United States Army has already been set forth in this paper.

The theory upon which rifle instruction is based is that man is not born a good rifle-shot any more than he is born a good penman or an accomplished horseman; that without training it is impossible to enable a man to handle or use an instrument with the requisite accuracy and advantage, certainly not that wonderfully-made instrument, the rifle. The theory assumes that the ordinary soldier can be taught to handle and care for a rifle just as men are taught to run a steam-engine or steer a boat, and can be made as careful of his ammunition as a farmer of his grain; he can learn the construction of his piece as easily as apprentices learn trades of handcraft—in short, he can be made a rifle-shot. This fact is attested by the proficiency of the companies in the Army, upon which care has been bestowed in rifle instruction.

By becoming a first-class shot the soldier acquires confidence in his weapon, a matter of no slight importance; for the moment a man becomes certain that he can kill whatever object of his own size may be within 500 yards of him, he has acquired a stock of self-knowledge which, in a military sense, multiplies his value many times over; and, *per contra*, the man who has not this self-confidence has his value diminished in the same ratio, and is at the mercy of his better-instructed adversary.

It is not claimed that a soldier is able to fire, in the presence of the enemy and in the excitement and confusion of battle, with anything like the precision achieved on the target ground. It is only claimed that the soldier, who at pleasure can put in bull's-eyes, centers, or even outers at all target-ground distances, is on this very account better able to throw into the enemy a much larger percentage of decisive bullets than though he were entirely uninstructed and unable to hit anything with certainty, whether on the target ground or in battle. To doubt this would be tantamount to asserting that skill with tools disqualifies a mechanic when called upon to do a specific piece of work.

APPENDIX 13.

SWELLED AND BURST RIFLE AND CARBINE BARRELS.

[Report of a Board of Officers convened at the National Armory, consisting of Capt. J. E. Greer, Capt. D. A. Lyle, Lieut. J. C. Ayres, and Lieut. C. C. Morrison, to examine and report upon seven Springfield rifles and one rifle barrel, received from the San Antonio Arsenal, with a view of discovering, if possible, the cause of the swelled and burst barrels of said rifles, and of any other defects or broken parts observed.]

NATIONAL ARMORY,
Springfield, Mass., June 12, 1882.

The Board met pursuant to the order. Present, all the members. They proceeded to the examination of the rifles submitted to them. An exhibit of the rifles examined and their condition is appended, marked A. Rifles 109588, 65434, 102634, 107757, 113304, 115597, and 109671, in addition to having the parts all worn by the usual wear and tear of service, have enlargements of the bore near the muzzle of the barrel, caused by being fired when there was some obstruction, such as a rag or sand, more probably the latter, in the muzzle. Such obstruction, and only such, will cause the swelling at this place. Rifle 102634 is both swelled and bursted at the muzzle. The strain which swelled the muzzle developed a sub-surface seam in the steel which had resisted the proof-charge, four times as heavy as the service-charge in powder and 95 grains heavier in lead.

Rifle 103128 has the bore scratched, probably by the ramrod, as it is bent and is of the old model, the edges of the end being sharp, which defect is corrected in the present model. The scratching may have been done by the headless shell extractor improperly inserted. This gun was fired for accuracy and gave fairly good results—about as good as the average gun.

Two broken rod bayonet-springs were submitted to the Board; both were broken near the catch-stud. A change of model proposed by the commanding officer, in which the form of the stud and spring is altered, will probably greatly correct this evil.

There being no further business before the Board, it adjourned subject to the call of the senior member.

JOHN E. GREER,
Captain of Ordnance.
D. A. LYLE,
Captain of Ordnance.
J. C. AYRES,
Lieutenant of Ordnance.
CHARLES C. MORRISON,
Lieutenant of Ordnance.

NATIONAL ARMORY, *July* 24, 1882.

Respectfully returned to the Board for an examination of carbines and rifles received from Lieut. C. A. Howard, Ninth Cavalry, and Capt. A. A. Harbach, Twentieth Infantry. The Board will also examine the records of the Armory pertaining to this subject and give a concise statement of what has been done in the way of tests for causes of swelled and burst barrels; will cause other tests, if deemed necessary, to be made, particularly such as are most probable in actual service, arising from carelessness and neglect.

A. R. BUFFINGTON,
Lieutenant-Colonel of Ordnance.

APPENDIX A.—*Component parts of Springfield rifle.*

Part.	Number of rifle.							
	109588.	65434.	102634.	107757.	113304.	115597.	109671.	103128.
Barrel	Swollen	Swollen	Swollen & burst at muzzle.	Swollen	Swollen	Swollen	Swollen	Bore scratched.
Receiver	Worn	Worn	Worn	Worn	Worn	Worn	Worn	Worn.
Breech-screw	do	do	Worn, indented	do	Indented	do	do	do.
Breech-block	do	do	do	do	Worn	do	do	do.
Breech-block cap	do	do	do	do	do	do	do	do.
Breech-block cap-screw	do	do	do	do	do	do	do	do.
Breech-block, assembled	Worn, serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable.
Cam-latch	do	Worn	Worn	Worn	Worn	Worn	Worn	Worn.
Cam-latch spring	do	do	do	do	do	do	do	do.
Thumb-piece	do	do	do	do	do	do	do	do.
Extractor	Gone	do	do	do	do	do	do	do.
Ejector-spring	Worn	do	do	do	do	do	Gone	do.
Ejector-spring spindle	do	do	do	do	do	do	Worn	do.
Ejector-stud	do	do	do	do	do	do	do	do.
Firing-pin	Point broken	do	do	do	do	do	Gone	do.
Firing-pin screw	Worn	do	do	do	do	do	do	do.
Hinge-pin	do	do	do	do	do	do	Worn	do.
Hinge-pin stud	do	do	do	do	do	do	do	do.
Hinge-pin complete	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Unserviceable	Serviceable.
Front-sight	Worn	Worn	Worn	Worn	Worn	Worn	Worn	Worn.
Rear-sight base	do	do	do	do	do	do	do	do.
Rear-sight base-spring	do	do	do	do	do	do	do	do.
Rear-sight base-screws	do	do	do	do	do	do	do	do.
Rear-sight leaf	do	do	do	do	do	do	do	do.
Rear-sight buckhorn plate	do	do	do	do	do	do	do	do.
Rear-sight slide-plate	do	do	do	do	do	do	do	do.
Rear-sight slide-block	do	do	do	do	do	do	do	do.
Rear-sight slide-spring	do	do	do	do	do	do	do	do.
Rear-sight slide-screw	do	do	do	do	do	do	do	do.
Rear-sight centering pin	do	do	do	do	do	do	do	do.
Rear-sight joint-pin	do	do	do	do	do	do	do	do.
Rear-sight complete	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	do.
Butt-plate	do	Worn	Worn	Worn	Worn	Worn	Worn	do.
Butt-plate screws, long	do	do	do	do	do	do	do	do.
Band, upper	Worn	do	do	do	do	do	Parts gone	Parts gone.
Band-swivel	do	do	do	do	do	do	do	do.
Band-swivel hook	do	Bent	do	do	do	do	do	do.
Band-swivel pin	do	Worn	do	do	do	do	do	do.
Band, complete	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	do	do.
Band, lower	Worn	Worn	Worn	Worn	Worn	Worn	do	do.
Band-springs	do	do	do	do	do	do	do	do.

								do.
Guard-screws	do	do	do	do	do	do	do	do.
Guard-plate	do	do	do	do	do	do	do	do.
Guard-bow	do	do	do	do	do	do	do	do.
Guard-bow swivel	do	do	do	do	do	do	do	do.
Guard-bow swivel-screw	do	do	do	do	do	do	do	do.
Guard-bow swivel-rivet	do	do	do	do	do	do	do	do.
Guard-bow nuts	do	do	do	do	do	do	do	do.
Trigger	do	do	do	do	do	do	do	do.
Trigger-screw	do	do	do	do	do	do	do	do.
Guard complete	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	do	do.
Bridle	Worn	Worn	Worn	Worn	Worn	Worn	do	do.
Bridle-screw	do	do	do	do	do	do	do	do.
Hammer	do	do	do	do	do	do	do	do.
Lock-plate	do	do	do	do	do	do	do	do.
Main spring	do	do	do	do	do	do	do	do.
Main-spring swivel	do	do	do	do	do	do	do	do.
Main-spring swivel-rivet	do	do	do	do	do	do	do	do.
Sear	do	do	do	do	do	do	do	do.
Sear-screw	do	do	do	do	do	do	do	do.
Sear-spring	do	do	do	do	do	do	do	do.
Sear-spring screw	do	do	do	do	do	do	do	do.
Tumbler	do	do	do	do	do	do	do	do.
Tumbler-screw	do	do	do	do	do	do	do	do.
Lock complete	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	do	do.
Ramrod	Bent	Bent	Bent	Worn	Worn	Worn	do	do.
Ramrod-stop	Worn	Worn	Worn	do	do	do	do	do.
Stock (wood part)	Worn and split	do	do	do	do	do	do	do.
Tip	Worn	do	do	do	do	do	do	do.
Tip-screw	do	do	do	do	do	do	do	do.
Stock complete	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	do	do.
Side-screws	Worn	Worn	Worn	Worn	Worn	Worn	do	do.
Side-screw washers	do	do	do	do	do	do	do	do.
Tang-screw	do	do	do	do	do	do	do	do.

NATIONAL ARMORY,
Springfield, Mass., November 17, 1882.

In accordance with the directions of the commanding officer National Armory, to report more fully upon the probable cause of gun-barrels being swollen at the muzzle, the Board assembled. Present, Capt. John E. Greer, Ordnance Department, Lieut. J. C. Ayres, Ordnance Department, Lieut. C. C. Morrison, Ordnance Department; absent, Capt. D. A. Lyle, relieved from duty at the post.

The Board proceeded to examine the records of the post, and also considered the results of experiments made by direction of the commanding officer.

They find that in September, 1879 (*vide* Ordnance Notes 117), the following experiments were made by Captain Greer, Ordnance Department, as indicated by his report, as follows:

> Two condemned barrels were taken at random from a lot turned in from the field. Eight or ten rounds were fired from one of them, rags of various sizes having been inserted in the bore a little below the front sight without affecting the barrel the slightest. Sand next having been inserted in the muzzle, the barrel was shaken so as to remove all but a few grains which adhered to the fouling; the piece was then fired. This was repeated several times without swelling the muzzle. The barrel was then run into wet sand and the bore nearly filled for about an inch and a half. After firing in this condition the barrel was found swelled at the muzzle precisely like those that have been received from time to time from the field. Several pine plugs from 6 to 8 inches in length were then prepared of a size to fit the bore closely. The second barrel was fired twice with the plugs driven in dry, about one-half their length, twice driven in wet, and twice driven in dry, but afterwards swelled by steam both inside and outside, without injury to the barrel. The inclosed air probably forced the plugs out before the bullets reached them. A plug was then split in two to represent a broken tompion, the air being free to pass by the plug. It was thought the bullet might wedge on the remaining side of the plug, but the barrel was found uninjured after the shot was fired. Occasionally a cup anvil of the Frankford service shell has been found in the barrel after firing. It was thought possible that one of these might become wedged in the barrel and cause the swelling. To test this question an anvil was driven down squarely across the barrel just opposite the front sight. The piece was then fired, without injury to the barrel. A second anvil was driven down to the same position, but obliquely to the axis of the bore. No damage resulted from the firing. A long wad of cotton waste was then wet and rolled into a spiral and forced down the barrel several inches by the ramrod. The piece was then fired, when the barrel was found swelled a little beyond the wad, which was probably carried forward a few inches before the bullet wedged upon it.

Recently the following experiments were made by direction of Colonel Buffington, commanding. A barrel received from the field with a swollen muzzle was cut off back of the swell. The muzzle was then pushed into wet sand and the gun discharged, using the service cartridge, resulting in a swollen muzzle. A second similar gun-barrel was taken, the swollen muzzle cut off, the gun fired, the end thrust into dry sand and fired again, with no perceptible swelling; it was then fired twice more with the consequent increase of fouling, the muzzle end rested in dry sand dust, as might easily happen at target practice from carelessness; then it was fired again and the muzzle found to be swollen.

From these experiments it is evident that an obstruction in the bore, particularly sand, will cause a swelling of the barrel. That men frequently lay their guns down or stand with the muzzle resting in the sand no one will probably deny. Such action is liable to pick up sand in the muzzle, particularly after the gun has been fired, resulting in swelling the barrel after firing again. The swelling never takes place from firing a service cartridge when there is no obstruction in the bore. There have been proved here in the last eighteen years over 450,000 barrels, with the following charges: One charge, 280 grains of powder and 500 grains of lead, and one charge 250 grains of powder and 500 grains of lead, and there has never been an instance of a barrel swelling near the muzzle. Such is the testimony of the foreman in charge of proving barrels, and of the employé who has for years done the proving.

No barrel leaves the Armory without having been proved with these charges in addition to other firing with service cartridges. If in the firing of nearly 2,000,000 cartridges with an unobstructed bore in over 400,000 guns no case of swelling at the muzzle has occurred; and if by placing damp sand in the muzzle it occurs nearly every time, it seems but reasonable to draw the conclusion in general that the swelling must only occur when the bore is obstructed.

The Board examined the two rifles invoiced by Capt. A. A. Harbach, Twentieth Infantry, and the six carbines invoiced by Lieut. C. A. Howard, Ninth Cavalry, and find their condition as indicated in the appended sheet.

There being no further business before the Board, it adjourned *sine die.*

JOHN E. GREER,
Captain of Ordnance.
J. C. AYRES,
Lieutenant of Ordnance.
CHARLES C. MORRISON,
Lieutenant of Ordnance.

Approved:

A. R. BUFFINGTON,
Lieutenant-Colonel of Ordnance.

Component parts of Springfield rifle and carbine.

Part.	Number of rifle.		Number of carbine.					
	71845.	102529.	75200.	75458.	76427.	75473.	75006.	37043.
Barrel	Muzzle swollen	Swollen	Worn	Swollen	Worn	Worn	Worn	Worn.
Receiver	Worn	Worn	do	Worn	do	do	do	Old model, broken.
Breech-screw	do	do	do	do	do	do	do	Worn.
Breech-block	do	do	do	do	do	Hinge broken	do	do.
Breech-block cap	Broken	do	do	do	do	Worn	do	do.
Breech-block cap-screw	Worn	do	do	do	do	do	do	do.
Breech-block, assembled	Unserviceable	Serviceable	Serviceable	Serviceable	Serviceable	Unserviceable	Serviceable	Serviceable.
Cam-latch	Worn	Worn	Worn	Worn	Worn	Worn	Worn	Worn.
Cam-latch spring	do	do	do	do	do	do	do	do.
Thumb-piece	do	do	do	do	do	do	do	do.
Extractor	do	do	do	do	do	do	do	do.
Ejector-spring	do	do	do	do	do	do	do	do.
Ejector-spring spindle	do	do	do	do	do	do	do	do.
Ejector-stud	do	do	do	do	do	do	do	do.
Firing-pin	do	Broken	do	do	do	do	do	do.
Firing-pin screw	do	Worn	do	do	do	do	do	do.
Hinge-pin	do	do	do	do	do	do	do	do.
Hinge-pin stud	do	do	do	do	do	do	do	do.
Hinge-pin complete	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable	Serviceable.
Front-sight	Worn	Worn	Worn	Worn	Worn	Worn	Worn	Worn.
Rear-sight base	Old model	do	Old model	Old model	Missing	Old model	Missing	Old model.
Rear-sight base spring	do	do	do	do	do	do	do	do.
Rear-sight base screws	do	do	do	do	do	do	do	do.
Rear-sight leaf	do	do	do	do	do	do	do	do.
Rear-sight buckhorn plate	do	do	do	do	do	do	do	do.
Rear-sight slide-plate	do	do	do	do	do	do	do	do.
Rear-sight slide-block	do	do	do	do	do	do	do	do.
Rear-sight slide-spring	do	do	do	do	do	do	do	do.
Rear-sight slide-screw	do	do	do	do	do	do	do	do.
Rear-sight centering-pin	do	do	do	do	do	do	do	do.
Rear-sight joint-pin	do	do	do	do	do	do	do	do.
Rear-sight complete	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	do	Worn, serviceable.	do	Worn, serviceable.
Butt-plate	Worn	Worn	Worn	Worn	Worn	Worn	Worn	do.
Butt-plate screws, long	do	do	do	do	do	do	do	do.
Band, upper	do	do						
Band-swivel	do	do						
Band-swivel hook	do	do						
Band-swivel pin	do	do						
Band complete	Worn, serviceable.	Worn, serviceable.						
Band, lower	Worn	Worn	Worn	Worn	Worn	Worn	Worn	Worn.

Band-springs	do	do	do	do	do	do	do	do.
Guard-screws	do	do	do	do	do	do	do	do.
Guard-plate	do	do						
Guard-bow	do	do						
Guard-bow swivel	do	do						
Guard-bow swivel-screw	do	do						
Guard-bow swivel-rivet	do	do						
Guard-bow nuts	do	do						
Trigger	do	do						
Trigger-screw	do	do						
Guard complete	Worn, serviceable.	Worn, serviceable.						
Bridle	Worn	Worn	Worn	Worn	Worn	Worn	Worn	Worn.
Bridle-screw	do	do	do	do	do	do	do	do.
Hammer	do	do	do	do	do	do	do	do.
Lock-plate	do	do	do	do	do	do	do	do.
Main-spring	do	do	do	do	do	do	do	do.
Main-spring swivel	do	do	do	do	do	do	do	do.
Main-spring swivel-rivet	do	do	do	do	do	do	do	do.
Sear	do	do	do	do	do	do	do	do.
Sear-screw	do	do	do	do	do	do	do	do.
Sear-spring	do	do	do	do	do	do	do	do.
Sear-spring screw	do	do	do	do	do	do	do	do.
Tumbler	do	do	do	do	do	do	do	do.
Tumbler-screw	do	do	do	do	do	do	do	do.
Lock complete	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.
Ramrod	Broken	Bent						
Ramrod stop	do	Broken						
Stock (wood part)	Worn	Worn						
Tip	do	do						
Tip-screw	do	do						
Stock complete	Worn, serviceable.	Worn, serviceable.						
Side-screws	Worn	Worn	Worn	Worn	Worn	Worn	Worn	Worn.
Side-screw washers	do	do						
Tang-screw	do	do	Worn	Worn	Worn	Worn	Worn	Worn.

Component parts peculiar to Springfield carbine.

Part.	Number of carbine.					
	75200.	75458.	76427.	75473.	75006.	87043.
Butt-plate	Worn	Worn	Worn	Worn	Worn	Worn.
Butt-plate screw, short	do	do	do	do	do	do.
Butt-plate cover	do	do	do	do	do	do.
Cover-spring	do	do	do	do	do	do.
Cover-spring screw	do	do	do	do	do	do.
Cover friction-spring	do	do	do	do	do	do.
Cover stnd-pin	do	do	do	do	do	do.
Butt-plate complete	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.
Swivel-bases	Worn	Worn	Worn	Worn	Worn	Worn.
Swivel-bar	do	do	do	do	do	do.
Swivel-bar ring	do	do	do	do	do	do.
Swivel complete	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.
Guard-bow	Worn	Worn	Worn	Worn	Worn	Worn.
Guard complete	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.	Worn, serviceable.
Stock (wood part)	Split	Worn	Split	Worn	Worn	Worn.
Stock complete	Unserviceable	Serviceable	Unserviceable	Serviceable	Serviceable	Serviceable.

APPENDIX 14.

DIRECT APPLICATION OF POWER.

BY LIEUT. COL. A. R. BUFFINGTON, ORDNANCE DEPARTMENT.

(1 plate.)

NATIONAL ARMORY,
Springfield, Mass., April 9, 1883.

To the CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

SIR: In 1873 or 1874 I perfected the mechanism for my notion of direct application of power to a crank arm, securing uniformity of work and motion. I never used or published the conception; but I have quite often spoken of it and described it to others, including the Armory draftsman, Mr. C. A. Emery, who recently informed me that he had seen, two or three days before, at a newsdealer's in Springfield, a publication containing a representation and description of an engine having connection with the crank similar to my design. This (the New York "Mechanics, a Weekly Journal of Engineering and Mechanical Progress," issue for January 6, 1883) he obtained for me; and on page 3 may be seen the illustration and description referred to, of "the Davis new direct-acting steam engine." In this description it is stated:

> From its compact form the engine has excited a good deal of interest among engineers, and we believe that it has been inspected by several naval engineers from Washington, with a view to ascertaining its adaptability for naval purposes; its great power, small weight, and the direct transmission of the strains making it especially desirable.

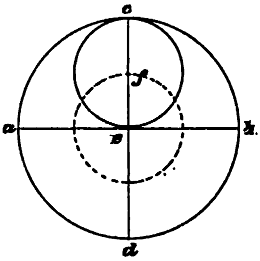
This language suggested to me the propriety of making known my design to the Navy Department, as possibly it might be of service, particularly at this time, when the building of new vessels is contemplated.

I therefore, below, give a description, and inclose herewith a plate, the latter, not drawn to any scale and not intended to represent an *engine*, being merely outlines of two cylinders, showing the manner of making the connection with the crank. This letter and inclosures I send in duplicate, one set for transmission to the Hon. Secretary of the Navy, the other for an Ordnance Note, should you deem it of sufficient interest to publish it. It should be remarked that Mr. Davis's design and mine are, though based on the same well-known geometrical principle, radically different in application. For such work as driving large vessels, or for work of variable resistance liable to be attended with shocks to the system, the crank connection of Mr. Davis, it seems to me, would be weak; it also appears to me an "unmechanical" construction. I have used the principle in the construction of a depressing gun-carriage (Ordnance Memorandum, No. 16), a magazine fire arm (Report of the Chief of Ordnance, 1878), a "mechanical curiosity" (Ordnance Note, 190), and in other ways. The present application of it, it is believed, would be particularly useful for "twin-screw" vessels.*

THEORY.

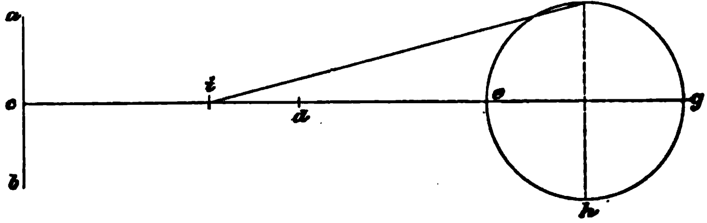
Any point of a circle *rolled* around inside of another twice as great will describe a right line on the plane of the greater. Two points, the extremities of a diameter, will describe right lines perpendicular to each other. The middle point of this diameter—being the center of the smaller circle—will describe a circle about the center of the greater; thus (Fig. 1), *a b* and *c d* would be the right lines described by the points *e* and *c*; and the dotted circle, the one described by the point *f*, the center of the smaller circle.

Fig. 1.



Here are, aside from the mechanical difficulties, all the conditions necessary to convert the right line paths of the "cross-heads" of two piston-rods into circular motion, securing direct application of power, uniform motion, and uniform work—uniform work in the sense that the cross-head of each piston-rod will travel equal paths for every quarter of the circle described by the crank-pin, and, considering the *reciprocal* action of power applied in the direction of the two piston-rods—that is, when one is "on the center" the other has its greatest power on the crank-pin, and *vice versa*—the power exerted at each point of the path of the crank-pin will be about as constant and uniform as machinery can make it, if it be not absolutely so. The difference between such a combination and the ordinary one having a "connecting-rod" may be seen by a consideration of Fig. 2, *a b*, representing a cylinder-head; *c d* the path of the cross-head of piston-rod; *e*, *f*, *g*, *h*, the path of the crank-

Fig. 2.



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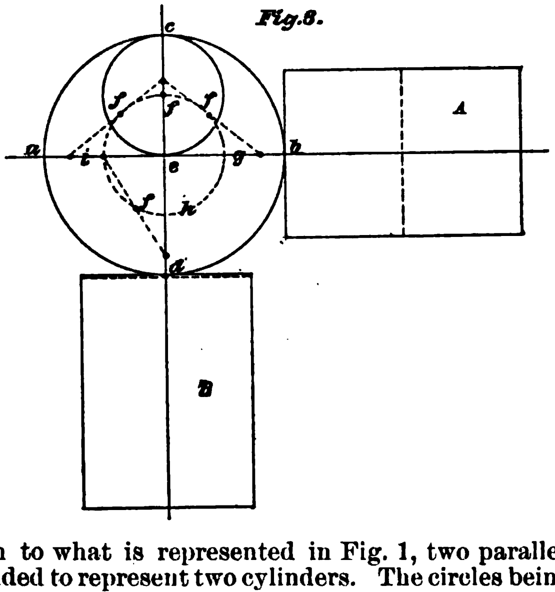
* Suggested by a naval engineer officer; but it would not be, unless the screws were alike and turned in the same direction. Whether "twin" screws are so made, and used, I do not know.

pin; and *i f*, the connecting-rod. In moving the crank-pin over the first quarter, *e f*, the cross-head will travel from *c* to *i*; but in moving it over the second, *f g*, the cross-head will travel only from *i* to *d*. P representing the power, P × *c i* will represent the quantity of work performed during the first quarter, and P × *i d* will represent the work performed during the second quarter; but as *c i* is much greater than *i d*, the quantity of work performed during the first quarter—a fourth—is much greater than during the second quarter—also a fourth—of the circle described by the crank-pin. Now, the resistance remaining constant, the motion must be variable, producing vibrations and changes injurious to the machinery, and not conducive to economy in expenditure of power. The same thing obtains with the third and fourth quarters of the crank-pin's path; and it will be readily seen that this condition of things cannot be altered by any number of cylinders working on the same crank-pin; more uniformity of motion may be obtained, but the conditions of expenditure of power remain the same for each cylinder.

So far, in principle, the constructions of Mr. Davis and the writer are identical, but in the application the difference is radical. There are mechanical difficulties in the way, to overcome which, constitutes the problem. To better explain the application, it may be well to go a little more into the details of how *generally* the principle is used. If not understood from the foregoing explanation, Fig. 3 may make it clearer.

Fig. 3.



In addition to what is represented in Fig. 1, two parallelograms, A and B, are added to represent two cylinders. The circles being discarded altogether, let *c e* represent a beam, and the lines *a b* and *c d* the fixed ways or "guides" of the cross-heads, pinned, like a crank to a connecting-rod, to the beam at *c* and *e*. As the figure stands, the piston-rod of A would be at the half stroke and that of B at the full stroke and "on a center." Two more cylinders may be added at the points *a* and *c*, and the piston rods made continuous; but it must be understood that the cross-head guides must be in different planes; that is, the sections of the cylinders represented by A and B are parallel, but in different planes perpendicular to the working shaft, and far enough apart to accommodate the thickness of the beam *c e* and the mechanism of attachments. From this construction it will be evident that the ends of this beam will be moved in right lines, and the center of it, *f*, be made always to describe a true circle. To attach this point in some way to the crank of the working-shaft, or to construct a beam, *c e*, one point of which shall describe a circle in a different plane, but parallel to this one and *outside* of the other mechanism, so that it shall be available for the crank-pin circle, is the mechanical problem. Presuming this is solved, an examination of Fig. 3 will discover what is stated as to uniformity of motion and work.

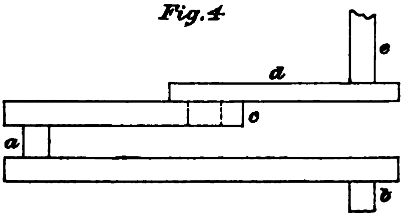
The cross-head of A in traveling from *b* to *e* will move the crank-pin through the first quarter of its path, corresponding to *f g;* in moving from *e* to *a* it will move it through the second quarter; but *e b* = *e a* and P × *e b* = P × *e a;* therefore, the quantity of work performed will be the same. The same is true for the remaining quarters; but being on the center twice during a full stroke, the power varies both ways from zero to its maximum at the half stroke. But when on the centers the companion cylinder is always at the half stroke—at its greatest power. As one gradually increases from zero to the maximum the other decreases from the maximum to zero, the leverage of one gaining as the other loses on the crank-pin, maintaining, if the power remain constant, about an uniform energy at each point of the crank-pin's path. The dotted lines show different positions of the beam *c e*, and, where it intersects the dotted circle, of the point *f*.

It will be observed that, with this combination, the working-shaft crank-lever is but one-fourth the length of the stroke, instead of one-half, as in the ordinary combination, but each piston-rod's power is doubled on the crank-pin, which in every position is midway between the fulcrum and the power in reference to each rod.

In Mr. Davis's engine, ways or guides for the cross-heads are not used; the piston-rods are prolonged beyond the cross-heads and into "boxes" at *a* and *c*, being supported only at the four points—two of which are the packing-boxes of the cylinder-head—*a*, *d*, *b*, and *c*. The piston-rods, therefore, sustain the *thrust* of the beam connecting them without support, except at those points, and are, moreover, twice as long, unless using *four* cylinders, as is necessary.

The problem of getting *to* the crank-pin of the working-shaft is solved by Mr. Davis by means of a beam returning upon itself far enough to pass the center and allow for a crank pin bearing; thus, Fig. 4, *b a c*

Fig. 4.



being the beam, *a* and *b* the projections or journals, working in the cross-head boxes of piston-rods; the returning branch *a c*, passing outside of the rod connected at *a*, permits, as shown, a connection with the crank-pin of crank *d*, *e* being the working-shaft. The whole work, therefore, of the system is thrown upon the rigid connection *a* of the two arms of the beam; the disadvantage of which, being apparent, need not be discussed.

The writer's solution is based upon the use of an "idler" crank, when but one working-shaft is to be driven—unnecessary when two are driven, as in twin-screw vessels—and may be easiest explained by showing how one of two parallel lines of shafting may drive the other by a rigid connection; thus, in Fig. 5, it being desired to drive the line of shafting *b* by *a* through a rigid connection (they may be opposite thus, ═══, or one the extension of the other on a different line, thus, ——— ———). Equal cranks A and B being put on the ends of the shafting and an equal "idler" crank C at any convenient distance on a short shaft *c*, sufficiently long for bearings, a rigid beam, K, attached to the three, as shown, will transmit any motion of A to B. If the line of shafting *a* and crank A be conceived to be removed and through the crank-pin hole in K, thus left vacant, a journal be passed having two crank-like, equal arms (thus, Fig. 6 *k* representing it, and E D the equal arms, the total length *c e* being equal to and constituting the beam *c e* of Fig. 3—that is, half the stroke), the combination will present the writer's solution of getting *to* the working-shaft. The two projections *a* and *b*, Fig. 6, passing into the cross-heads of the piston-rods, move in righ lines; the center of *k* describes a circle, and in doing so will carry the beam K, Fig. 5, in a circle, which, when connected with an "idler" crank, as shown in Fig. 5, will drive a shaft at any practicable distance, no matter what angle it may make with the beam *c e*; that is, describing circles with radii *c a* and *a b* (Fig. 5) from *a* as a center, the working and idler shafts may be placed at any corresponding points on these circles. This property enables the engine to be placed in any position with respect to the working-shaft, either above, below, or to one side of it. The positions would be limited in the case of two working-shafts, one taking the place of the idler, as in a twin-screw vessel; the position midway between them would be the natural one, making the working *f* (Fig. 3) midway of the beam K (Fig. 5). It may be observed that the distance of the idler crank from the source of power is not limited, except to be far enough from the fixed and moving parts of engine to move as required, all of which is conducive to compactness—economy—of space.

Fig. 5.

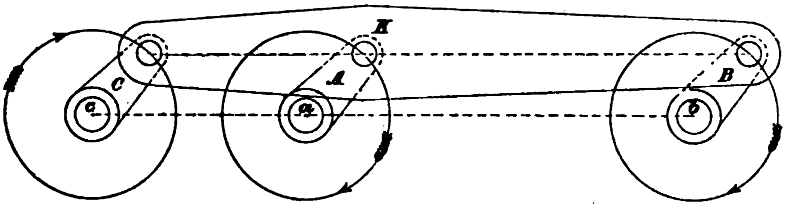
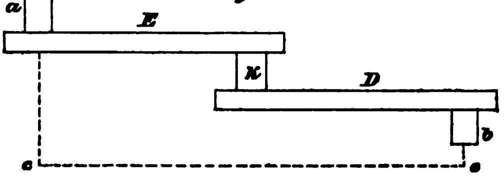


Fig. 6.



DESCRIPTION OF PLATE.

A and B representing two steam cylinders, C, D will represent the cross-head guides, K the rigid beam uniting the idler crank (which can be either I or W), and the center *f* of the beam *c e* (whose extremities connect with the cross-heads *x* and *y*) to the working-crank I or W. Fig. 1 of the plate is an elevation and Fig. 2 a partial plan and projection on a plane perpendicular to the axis of cylinder B, showing a projection of a section at *f*, of the beam K. Fig. 3 shows a side view of beam K and connections. Fig. 4, one of the double crank-shaped beam (which, having to pass through the beam K, must be made in two parts) connecting the piston-rod cross-heads.

It may readily be seen that two or four cylinders may be used, placed very compactly, and all, with the idler crank, built—attached—to the frame or bed.

For the cross-head guides C, D "parallel motions," of course, may be used. One of the most compact and convenient would be a reversed "Peaucellier cell," as indicated in Fig. 7. On account of the uniformity of motion and work, engines built on this plan would be more suitable than the ordinary ones for running the machinery used in electric lighting.

Fig. 7.

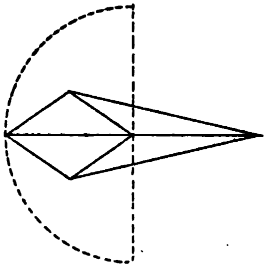


Fig. 3.

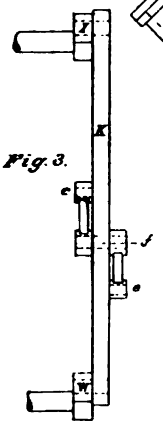


Fig. 1.

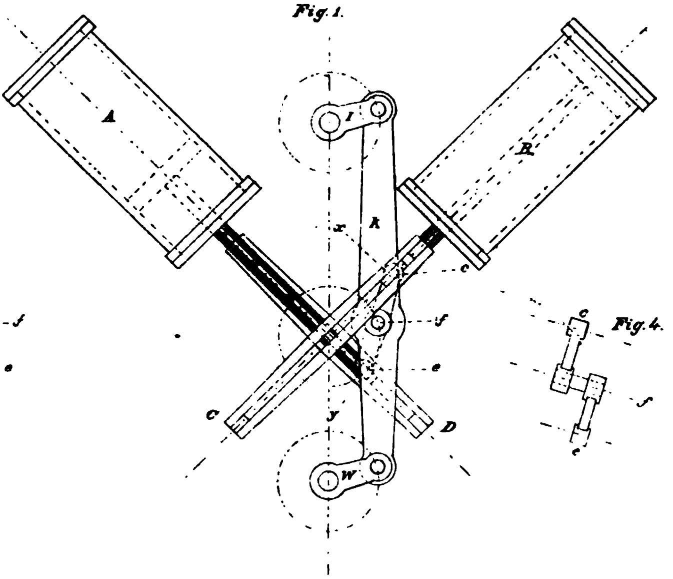
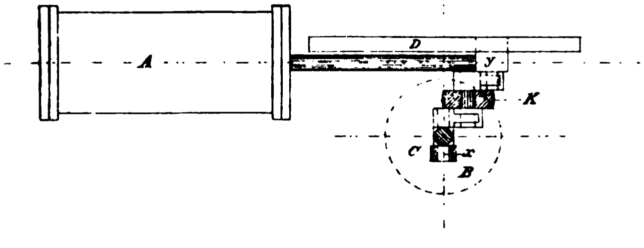


Fig. 4.

Fig. 2.



Appendix 14—1883.

APPENDIX 15.

BARTLETT'S FORMULAS.

[Being a continuation of Appendix 22 in report of 1881.]

BY MAJOR GEORGE W. McKEE, ORDNANCE DEPARTMENT.

NEW YORK ARSENAL, *April* 9, 1883.

The CHIEF OF ORDNANCE, U. S. ARMY, *Washington, D. C.:*

SIR: In Ordnance Notes No. 148 an attempt was made to show the insignificance of the torsion and longitudinal strains to which all rifled guns are subjected, as compared with the circumferential or tangential. In order to render the formulas as simple and easy of application as possible, Equation (5) was differentiated by me after "substituting y for l," giving—

$$\frac{d^2\psi}{dt^2}=-\frac{2\pi V^2}{\nu n y^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (6)$$

This would give values for y at all points of the bore in the resulting formulas, and tend to reduce any elements of uncertainty as to corresponding pressures, which have to be determined by instruments and by calculation. This application I am convinced is not correct, and there can be no doubt that it would be better to differentiate Equation (5)—substituting for V its value, $\frac{dy}{dt}$. Professor Bartlett informs me that this increment of the velocity should not be neglected, and no objection whatever can be made to this latter form of differentiation. This would be—

$$\frac{d^2\psi}{dt^2}=\frac{2\pi}{nl}\cdot\frac{d^2y}{dt^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (6)$$

Therefore, as I believe this subject to be necessarily interesting to those engaged in the investigation of the strains induced by gunpowder, and as I have had many inquiries from officers and others studying these strains, I herewith submit some explanatory remarks and references, together with a view of the case from another standpoint. Lieut. A. H. Russell, of the Ordnance Department, has corresponded with me a great deal—has taken much interest in the matter, and it is mainly due to him that this appendix has been submitted. In fact all of the explanations and most of the work are his, and to him is due any credit that may attach to the elucidation of the subject.

The value of the cotangent $\frac{nl}{2\pi}$, as given in Professor Bartlett's memoir (page 17), and illustrated in the figure below, is that corresponding to the angle at a unit's distance from the axis; and, as used in the memoir, it is probable that ν was omitted from the demominator by a typographical error, which escaped notice, as the discussion was not carried further. As in practice in constructing a forming bar* for the rifling of a gun this cotangent for a point on the surface of the bore would be $\frac{nl}{2\pi\nu}$, the changes are made correspondingly.

Hence we would have, Equation (3)—

$$y-\frac{nl}{2\pi}\psi=0;$$

Eq. (4) . . . . $L=\nu\psi-\frac{2\pi\nu}{nl}y=0;$

Eq. (5) . . . . $\frac{d\psi}{dt}=\frac{2\pi V}{nl};$

Eq. (7) . . . . $v=\frac{V}{nl};$

Eq. (8) . . . . $d=nl.$

From Eq. (4) we would have—

$$\left.\begin{array}{r}\nu\delta\psi-\frac{2\pi\nu\delta y}{nl}=0\\ \delta\nu=0\end{array}\right\}$$

Whence, taking the partial differential coefficients of L with reference to ψ and y—

$$N=\lambda\sqrt{\left(\frac{dL}{\nu d\psi}\right)^2+\left(\frac{dL}{d\nu}\right)^2+\left(\frac{dL}{dy}\right)^2}=\lambda\sqrt{1+\frac{4\pi^2\nu^2}{n^2l^2}},$$

and we will find—

$$A^1=\frac{nlf+2\pi\nu}{\nu(nl-2\pi f\nu)}.$$

The resulting formulas would be—

$$A=\frac{nlf+2\pi\nu}{nl-2\pi f\nu}; \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (20)$$

$$\frac{I}{\nu}\cdot\frac{d2\psi}{dt^2}=\frac{p_1.\pi.\nu.K_1^{\ 2}\cdot\frac{2\pi}{nl}}{1+K_1^2.\frac{2\pi}{nl}\cdot\frac{A}{\nu}}; \quad . \; . \; . \; . \; . \; . \; . \; . \quad (22)$$

$$P-M\frac{d2y}{dt^2}=\frac{p_1.\pi.\nu.K_1^{\ 2}\cdot\frac{2\pi}{nl}\cdot A}{1+K_1^2.\frac{2\pi}{nl}\cdot\frac{A}{\nu}}. \quad . \; . \; . \; . \; . \; . \quad (21)$$

The work of the torsion strain would be expressed by the equation—

$$\frac{I}{2}\left(\frac{d\psi}{dt}\right)^2=\frac{W}{2g}.K_1^2.\frac{4\pi^2}{n^2l^2}V^2,$$

V being the linear and $\frac{d\psi}{dt}$ the angular velocity at the muzzle.

It is remembered that p_1 denotes the pressure of the gas on one square foot of surface at whatever point of the bore the strain is measured.

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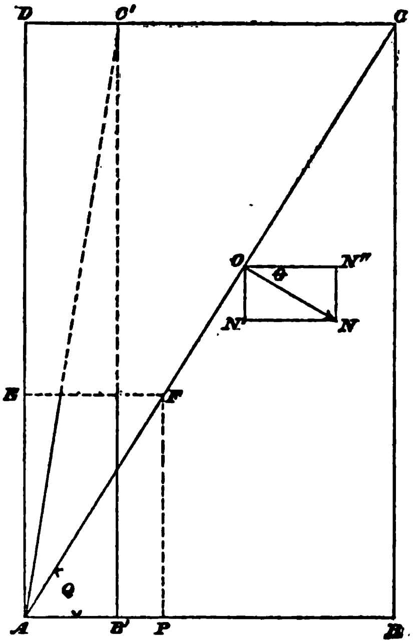
* See Text Book on Construction of English Ordnance, page 40.

In applying these formulas it will be seen that the torsion and longitudinal strains are less than those derived from the formulas in Ordnance Notes 148, and are still further corroborative of Professor Bartlett's statement that "the failure of rifled guns must be sought in some cause other than the superaddition of the pulling and twisting strains to that which acts to split the piece; and, so far as the principles of rifling are concerned, these guns may be made as safe as the common smoothbores."



AB' $=2\pi$; AB$=\pi\nu$.

AC' =Development of helix at units distance from the axis.

AC =Development of helix of actual groove of the gun.

N =Normal pressure on edge of land.

ON' =Component of N parallel to axis of gun $=\text{ON} \sin\theta=\lambda\frac{2\pi\nu}{nl}$.

ON''=Component of N perpendicular to axis of gun=ON $\cos\theta=\lambda$.

S =Any indefinite arc of actual helix of groove.

fN =Friction at groove.

fN $\sin\theta$ =Component of friction perpendicular to axis.

$\nu\delta\psi'$ =Elementary path, perpendicular to axis, on surface of bore.

fN $\sin\theta\nu\delta\psi$ =Work in this direction.

fN $\sin\theta\nu$ is therefore the force at a unit's distance from the axis, which is equivalent to the component of friction perpendicular to the axis; *i. e.*, it is the moment of the perpendicular component of friction.

$\lambda\nu$ in Equation (10) represents the tangential component of the force N at a unit's distance from the axis; hence λ will represent the same component at the distance ν from the axis, or on the surface of the bore.

APPENDIX 16.

CAPTAIN DUTTON'S REPORT ON THE TERTIARY HISTORY OF THE GRAND CAÑON DISTRICT.

The Chief of Ordnance desires to bring to the notice of the officers of the Ordnance Department the verdict of scientific opinion upon the recent work of Capt. C. E. Dutton, of the Ordnance Department, entitled The Tertiary History of the Grand Cañon District. For this purpose he causes to be printed herewith a review from the English journal, Nature, of February 15, 1883, by Prof. Archibald Geikie, F. R. S., director of the Geological Survey of Scotland.

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

In a handsome quarto volume with a large atlas of maps and colored views, the recently constituted United States Geological Survey begins its series of memoirs descriptive of the geological structure and history of the country. Most appropriately the subject selected for illustration is at once the grandest and most unique feature in the geology of the United States, and to which indeed there is no parallel elsewhere in the world. Ever since the early report by Ives and Newberry, in which the marvels of the Rio Colorado of the West were first made known, there has been a strong desire among geologists to learn more of that region, to have accurate measurements and careful drawings, and to be told authoritatively the details and the history of what they could not but admit to be the most stupendous example of river erosion on the face of the globe.

Major Powell's bold descent of the river, and the charming volume in which he described it, threw much fresh light on the wonders of the cañons. But he had no opportunity of properly exploring the surrounding regions, though we look forward to his return to the scene of his exploits and the consequent elaboration of another memoir discussing the whole problem of the origin and history of the geological features of that remarkable area. Pressure of other duties has prevented him from realizing this hope. But, though unable himself to resume this task, he deserves our best thanks for having induced the late director of the survey, Mr. Clarence King, to intrust the detailed survey of the Grand Cañon to Capt. C. E. Dutton, who had already done excellent service among the high volcanic plateaus further north. Captain Dutton unites some of the highest qualities of a geological explorer. He is an excellent stratigrapher, a good petrographer, an enthusiast in the study of rock-sculpture, writes clearly and pleasantly, has a physical frame capable of carrying him triumphantly through any amount of physical fatigue, and is the happy possessor of a bright and cheerful nature, that must lighten the hardships of camp life in the remote West, both for himself and for his companions. We can well imagine how such a man, wandering among the lofty plateaus of Utah that had been assigned to him for exploration, should have cast many a longing gaze southward to that strange, wild desert region of rocky platforms and winding mesas through which the gorges of the Colorado and its tributaries have been sunk; how he should have been unable to resist the temptation to stray into that wonderland; and how he must in some measure have almost welcomed the blasts of early winter that drove him down from the survey of the plateaus, and allowed him to journey through the cañon country on his way back to the Mormon settlements and nearest railroad.

When at last the task of actually exploring and describing that region was intrusted to him, he already possessed a general acquaintance with its character and with many of its details. A stranger who first finds the cañon scenery before him is so excited by its novelty and grandeur, that for a time he feels utterly bewildered. Only after his eye has in some measure recovered its power of grasping the broad effects, without being lost in the details, does he begin to realize what are the elements of this stupendous grandeur. But Captain Dutton had gone through this preliminary training. He had been led to scrutinize the scenery in detail, to discover the relations of part to part, and to speculate upon the evolution of the whole. Yet no one can read his pages without feeling that this analytic process has in no way dulled his sense of the beauty and majesty of the scenery. His words glow with the light that floods those flaming precipices. The blue aerial perspective of chasm and cliff receding into the dim distance in the central gorge seems to rise before our eyes as we read. With no irreverent hand does he tear the mask off the face of nature. Rather does he make us feel how deeply the mystery of the scene has entered into his soul, as he gently lifts the veil that we may see a little way within, even as far as he has himself been enabled to penetrate.

And this is the true spirit in which such scenery should be described and discussed. The man who could sit down and dissect these cañons in cold blood, and with as little emotion as he would show in cutting up a joint of beef, would be a creature not to be envied. Nowhere in this world does the scenery appeal so powerfully to the imagination. Among the Alps the rocks have been so stupendously crumbled that we may be pardonably at a loss to tell how far the outlines of a mountain are due to subterranean movements or subsequent erosion. But among the western cañons there is no room for any such doubt. The rocks lie for thousands of square miles as flat as when they were laid down upon the floors of ancient seas and lakes, and their horizontal, undisturbed beds may be followed by the eye, winding in and out from cliff to cliff, preserving the same breadth, color, features, and serving as so many datum-lines from which to measure the amount of solid rock that has been removed from the gorges. In tracing back the origin of these landscapes, and seeking out the causes of their infinite variety of detail, yet marvelous harmony of effect, the mind naturally compares them with the feeble illustrations of erosion with which alone we are usually personally familiar. Such a comparison, however, will almost suggest a doubt as to whether we ever before could have had any proper conception of what the power of running water actually is, so utterly beyond description is the impressiveness with which this power is now realized. Nor is one disposed to deny that nowhere else is the dominant influence of geological structure upon the ultimate contours developed by erosion so significantly displayed. On every part of the scenery the story of its origin is impressed in characters that cannot be mistaken. Yet these characters are on so colossal a scale that dry, prosaic language of ordinary geological description seems utterly incongruous when applied to them. It must be a difficult task to preserve the sober decorum of scientific treatment and to convey at the same time an adequate impression of the infinite majesty of the subject.

Captain Dutton may be congratulated on having accomplished this task with as large a measure of success as probably was achievable. Without entering into strategraphical details he addresses himself to the problem of the origin and history of the erosion that has converted the level rock platforms of the Colorado River into their present profoundly trenched condition. Sketching briefly but clearly the general geographical features of the region and their relation to the underlying geological structure, he presents the reader with a series of pictures of the various types of scenery. He shows how everywhere the evidence arises of vast denudation. Not only have the wide valleys and deep gorges been excavated, but an enormous amount of material has been worn away from the broad rocky terraces. From the high plateaus of Utah the Mesozoic and Tertiary formations descend by a succession of broad terraces like a giant staircase to the platform of Paleozoic rocks. Captain Dutton gives reasons for his belief that the strata which end at the cliffs of these successive terraces once extended over the whole of the Grand Cañon district, and he estimates the amount of rock thus removed to have averaged probably 10,000 feet in thickness over an area of 13,000 to 15,000 square miles in extent. He bases this estimate partly upon the obvious continuity of the strata, and the improbability that they could have ended off upon the Carboniferous platform; partly upon the evidence of displacements whereby Paleozoic rocks, formerly buried at least 10,000 feet below the sea-level under an accumulation of sediment of that depth, have been again uplifted into the lofty plateaus of the Colorado; partly upon an argument from the history of the drainage-lines of the district. In this last argument, developing the views so forcibly expressed by Jukes many years ago for the rivers of the south of Ireland, and more recently applied by Powell to the stupendous illustrations in the Colorado basin, he shows that the present courses of the rivers are so entirely independent of structural features that their position is inexplicable save on the interpretation that when the streams began to flow these features had not revealed themselves. He thus smooths over the faulted Carboniferous platform, piles over it a covering somewhere about two miles thick of Mesozoic and Tertiary strata, and makes the rivers begin their first erosion on the surface of this covering. The faulting, plication, and uplifting have taken place subsequently; but meanwhile the rivers have kept their courses, incessantly sawing their way downward into lower layers of rock, and across the dislocations and folds that subterranean disturbance might throw across their path. No thoughtful student of this subject can refuse his assent to the solution of the problem so well worked out. In tracing the geological history of the cañon region we find at the bottom of all the visible strata a foundation of ancient crystalline Archæan rocks, and also crumbled and broken masses of stratified formations, referred with more or less confidence to the Silurian and Devonian periods. The disturbance and extensive denudation of the older Paleozoic masses had been effected before the lowest of the vast conformable series of formations in this region began to be deposited, for the latter lie upon the upturned edge of the former, as on a platform—an impressive feature in the scenery. Continuous sedimentation sometime in the Carboniferous period, appears to have been carried on with no sensible break up to the close of the Eocene period, until a total depth of at least 15,000 feet of sediment had accumulated. The Carboniferous portion is estimated at a thickness of 4,500 feet, the various Mesozoic formations at 9,000 or 10,000, and the portion of the Eocene lacustrine beds deposited were 1,000 or 1,200 feet.

Captain Dutton calls attention to the remarkable uniformity and persistency of the lithological character of each formation, while at the same time there is great diversity in those respects between the strata of different platforms. By far the larger proportion of the whole mass of conformable strata consists of sandstone, presenting on successive horizons the most extreme contrasts of structure and color, for they consist along certain platforms of adamantine quartzite; in others of massive cross-bedded sand-rocks, while they graduate also into shale, and these into marls. It is this alteration of strata, showing very different degrees of permanence, yet each retaining its normal character over vast areas, that affords the key to much that is most characteristic in the scenery of the region. The limestones are almost wholly confined to the Carboniferous system, where they occur both in the lower and upper divisions.

Another significant feature brought out by the survey is the evidence that sedimentation went on nearly at sea-level during the whole of Mesozoic time throughout the cañon province. As the Mesozoic strata are 9,000 or 10,000 feet thick, it is obvious that the sediments which were at or near the sea-level at the beginning had sunk to that distance below it by the end of the period. We have here, therefore, a consecutive series of shallow-water deposits not much less than 2 miles in vertical thickness. The Cretaceous rocks which form the uppermost division of this series are from base to summit banded with seams of lignite or coal and layers containing marine mollusca. They vary in different parts of the province from 3,500 to 8,000 feet in thickness. At the close of their deposition those movements appear to have begun which have culminated in the elevation of the sea-floor into the elevated plateaus that now form so prominent a feature on either side of the watershed of the continent.

With the advent of Eocene time the shallow sea-floor, in which sedimentation had been so continuous during the whole of the Mesozoic ages, began to be converted into wide fresh-water lakes. The Tertiary history of Western America is in large measure a record of the formation, duration, and effacement of these lakes, as the land gradually increased in elevation. In the plateau country the Eocene lacustrine deposits range from 1,000 to 5,000 feet in thickness. Great as this accumulation is, it unquestionably took place in comparatively shallow water over an area that was generally rising, yet was locally sinking, so that the lake persisted and remained shallow; for its depth was reduced by the deposit of sediment as fast as it was increased by subsidence. The waters appear to have dried up from south to north, and finally disappeared somewhere in the area of the Uinta Mountains.

It was on the floor of this desiccated lake that the drainage system of the Colorado River began, somewhere about the close of the Eocene period. During the vast succession of ages that have since elapsed, erosion has been continuously in progress, and the result is the scenery of the cañon region. Captain Dutton gives what appears to be good reasons for believing that the larger rivers flow along the same channels they took at the beginning, but that the minor tributaries, where any exist (and they are conspicuously absent in some wide districts), are comparatively recent in origin, and have been determined by modern surface conditions. The excavation of the Grand Cañon of the

Colorado has thus been going on ever since the Eocene period. During that enormous interval the climate of the region appears to have passed through successive oscillations. There is no more skillful feature of the volume before us than the way in which the scattered facts that bear on this question are marshaled to their places and made to tell their story. Ancient river beds, which for ages have been dry and are partly filled up with *débris*, open on the edge of the chasm. They doubtless discharged their waters into the main river at a time when rains were abundant and water-courses numerous. But their fountains have long since been dried up, and their fading channels are almost gone. But all the while the Colorado and its larger feeders, drawing their supplies from far, well-watered uplands, have continued their task of erosion until they have sunk their channels in some places more than a mile below the level of the plateau across which they flow.

The process of the excavation of the Grand Cañon is treated at length, and much new information is given as to its varying conditions. The details of the erosion are described with great clearness. The two final chapters, wherein these subjects are discussed, contain much that is suggestive, and deserves careful perusal by all who take interest in questions of denudation. They are condensed pieces of reasoning which cannot be intelligibly summarized here, and which, indeed, one is hardly prepared to find in an official report. Like his colleague, Mr. G. K. Gilbert, Captain Dutton properly lays great stress upon the influence of an arid climate as one of the chief factors in cañon excavation. He points out how the absence of vegetation exposes the surface of bare rock to the action of rain. But it may be doubted if the scanty rains of the region can do more than remove materials already disintegrated. We have to account for the continuous lowering of the level of the plateaus and the removal of so vast a depth of stratified rock from their surface. Captain Dutton himself admits that most of the rain which falls upon the country is absorbed by the rocks, and gushes out in copious springs at the base of the cañon-walls, thereby notably increasing the volume of the river. But there is everywhere a perceptible disintegration of the rock at the surface. This decay cannot be attributed to frost, which, in so dry a climate, can have but small effect. It seems to be due in large measure to the superficial strain induced by a great daily range of temperature. And it is no doubt aided by the action of wind, which removes the loosened particles, and exposes a new surface to the same kind of disintegration.

In conclusion, reference must be made to the truly magnificent series of illustrations by which this monograph is accompanied. The maps of the atlas give the reader a clear mental picture of the general topography and geological structure of the region; but it is by the pictorial illustrations that he will be chiefly fascinated. These are scattered profusely through the text, and form an important feature in the atlas. Mr. Holmes, whose reputation for the accurate and artistic rendering of geological details is so well established, has here far surpassed all his previous efforts, and has produced the most impressive and instructive geological pictures that have ever been made. His large colored views of the Grand Cañon are in themselves a series of lessons in geology far more interesting and effective than can be supplied in words. The United States may be heartily congratulated on the first of the monographs of their geological survey. Let us hope that Congress will continue in the same liberal spirit the annual appropriations that have enabled the director of the survey and his associates to produce such splendid results.

ARCH. GEIKIE.

APPENDIX 17.

REPORT ON THE IMPROVED ARM-RACK FOR RIFLES, CARBINES, AND REVOLVERS MANUFACTURED AT ROCK ISLAND ARSENAL.

BY LIEUT. COL. D. W. FLAGLER, ORDNANCE DEPARTMENT.

(3 plates.)

Numerous improvements have been made in these arm-racks since the publication of Ordnance Note No. 125, in May, 1880. The most important of these are the following, viz:

The rifle-rack has been made larger.

A new locking device for greater convenience in locking and unlocking has been substituted for the old device.

A *middle* disk has been added to the carbine-rack, and the locking bands have been transferred to this disk, to prevent removal of carbines by taking out the tang screw and slipping up the *band*.

The box part proposed by Col. J. McAllister, Ordnance Department, has been substitued for the five round sticks to give greater strength and stiffness.

The suggestion made by Maj. F. H. Phipps, Ordnance Department, that a revolver-rack should be added to the carbine-rack has been adopted, and I have devised a revolver-rack and combined it with the carbine-rack.

An economical method of constructing the carbine-rack with a box post, especially with the added revolver-rack, has been devised, and this rack is now made with this post.

DESCRIPTION.

The rifle-rack is shown on Plate I.

The combined carbine and revolver rack is shown on Plate II.

Fig. 1, Plate III, shows the method of constructing the revolver-rack, and of attaching it to the top disk of old carbine-racks now in service.

Although the details of construction are sufficiently shown in the drawings, the following description may be of use in the manufacture of the racks:

Details common to both rifle and carbine racks.

The feet, a a, wrought iron, to be screwed to barrack floors.

Bottom disk, A: Three thicknesses of poplar plank glued together, grain of wood crossing at right angles; 20 triangular pieces 1-inch poplar, *b b b*, to separate butts of arms; *c*, band of ⅛ by 1½ inch wrought iron, secured by 12 No. 10 wood screws, with heads filed off to bottom of slot, and flush with band to render unscrewing impossible.

Box post, B: 1 inch pine glued and nailed together, 3 feet 10 inches long for rifle-rack, 3 feet 11 inches long for combined carbine and revolver rack, grooved into bottom disk of both racks and into top disk of rifle-rack.

Assembling rod, C: ⅜-inch wrought iron, countersunk hole in bottom disk, filled with wood to prevent removal of nut.

Locking bands, D: Of wrought iron, covered with black collar leather to prevent marring the arms; dimensions and details of *hinges h, hinge irons f*, stay irons *e*, and locking device are shown on drawings; *d* is a notch ⅛ inch deep, which catches the locking band when pushed through slot, and holds it until padlock is put in. The hinge irons are fastened with two rivets running through both irons and disk.

RIFLE-RACK.

(Plate I.)

Top disk, E: Two thicknesses of poplar plank glued together, grain of wood crossing at right angles This disk has the locking bands.

Bill of materials for one rifle arm rack.

MATERIALS.

24	feet 1½ by 24 inch poplar; top and bottom cleats, &c.
11	feet 1 by 14 inch pine, box post.
12	1½-inch No. 14 wood screws.
12	1¼-inch No. 10 wood screws.
6	¾-inch No. 8 wood screws.
1	brass padlock, Romer No. 69.
5	ounces glue.
1¼	pounds paint and varnish.
1	iron lock band, 1½ by ⅛ by 48 inches long.
1	iron bottom band, 1½ by ⅛ by 73 inches long.
2	iron hinge pins, 3/16 inch round, 5 inches long.
2	iron hinge straps, 1 by 3/16 by 10 inches long.
1	iron bolt, ⅜-inch by 4 feet 2 inches long.
3	iron feet, 1½ by ⅜ by 45 inches long.
3	iron clips, ¾ by ⅛ by 9 inches long.
2	pounds scrap collar leather.
0.05	ounce thread.
0.005	ball wax.

Weight, 54 pounds.

Combined carbine and revolver rack.

(Plate II.)

Middle disk, F: Two thicknesses of poplar plank glued together, with grain of wood crossing at right angles with square hole cut out of center to take the box post. *l l*, strips of poplar glued and nailed to box post, support the disk which is nailed to them; notches in this disk fit carbine closely just on top of band, to prevent band from being slipped up. This disk carries the carbine locking bands.

Revolver disk, K: Two thicknesses of poplar plank glued together, with grain of wood crossing at right angles; is supported by and secured to strips *k*, similar to middle disk. The notches in this disk are made to fit snugly both Colt's and Schofield, Smith & Wesson revolvers, caliber .45, in the position shown in the drawings. This disk carries the locking bands for the revolvers, and also prevents carbines from being lifted.

Top disk, L: Two thicknesses of poplar glued together with grain of wood crossing at right angles, nailed to strips *l* and *l*, which are nailed and glued to box post. Disk is notched, and strips *l* form a circle to fit snugly against butts of revolvers. Disk is secured by wrought-iron band ⅛ by ¾ inch, fastened by wood screws similar to bottom disk.

Bill of materials for one combined carbine and revolver rack.

MATERIAL.

39	feet 1½ by 24 inch poplar, bottom, middle, and upper disks.
4	feet 1 by 14 inch poplar, top and partitions.
11	feet 1 by 14 inches pine, box post.
12	1½-inch No. 14 wood screws.
30	1¼-inch No. 10 wood screws.
6	¾-inch No. 8 wood screws.
2	brass padlocks, Romer No. 69.
½	pound glue.
2½	pounds paint and varnish.
1	iron top band, ¾ by ⅛ by 44 inches.
1	iron revolver band, 1½ by ⅛ by 72 inches.
1	iron middle band, 1½ by ⅛ by 68 inches.
1	iron bottom band, 1½ by ⅛ by 73 inches long.
4	iron hinge pins, 3/16-inch round, 9 inches long.
4	iron hinge straps, 1 by 3/16 by 20 inches long.
1	iron bolt, ⅜ inch by 4 feet 2 inches long.
3	iron feet, 1½ by ⅜ by 45 inches long.
6	iron clips, ¾ by ⅛ by 18 inches long.
.74	pound scrap collar leather for revolver-rack bands.
.044	ounce thread, revolver-rack bands.
.003	ounce wax, revolver-rack bands.
1.87	pound scrap collar leather for carbine-rack bands.
.046	ounce thread, carbine-rack bands.
.004	ounce wax, carbine-rack band.

Weight, 77 pounds.

Revolver arm rack for attachment to old carbine rack now in service.

(Plate III.)

The revolver-rack disk K is the same as the revolver-rack disk K of the combined carbine and revolver rack. The top disk T, and the post P, are made of poplar turned to shape shown in the drawing. The bolts *p p* are issued to company officers with the rack.

To attach the revolver-rack to carbine-rack place it on top disk of carbine-rack and mark positions for bolt-holes so that revolvers will come opposite intervals of carbines. Bore the holes in carbine-rack top disk, put in bolts with nuts below, and rivet up head of bolt to prevent removal of nut.

Weight of revolver rack, 11 pounds.

PLATE I.

Fig 1
Vert.l Section at a b

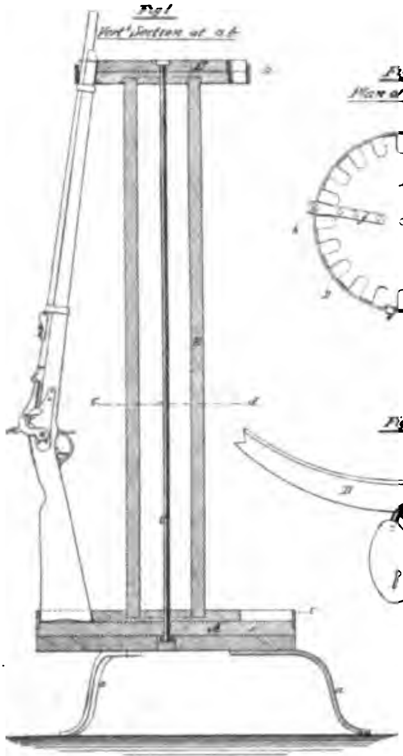


Fig 4
Plan of upper Disk

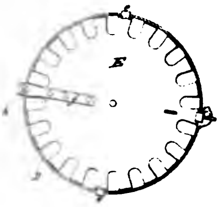


Fig 2
Elevation

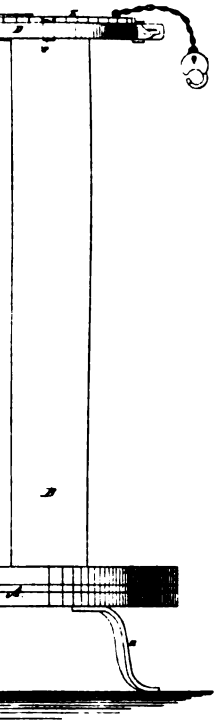


Fig 5.

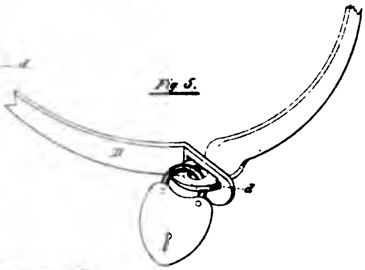
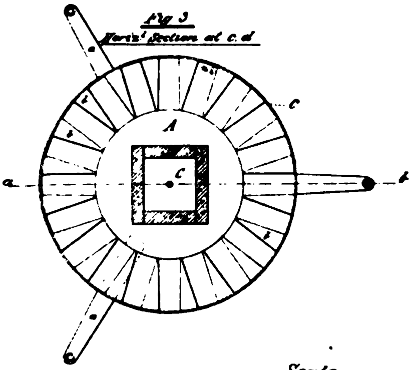


Fig 3
Horiz.l Section at c. d

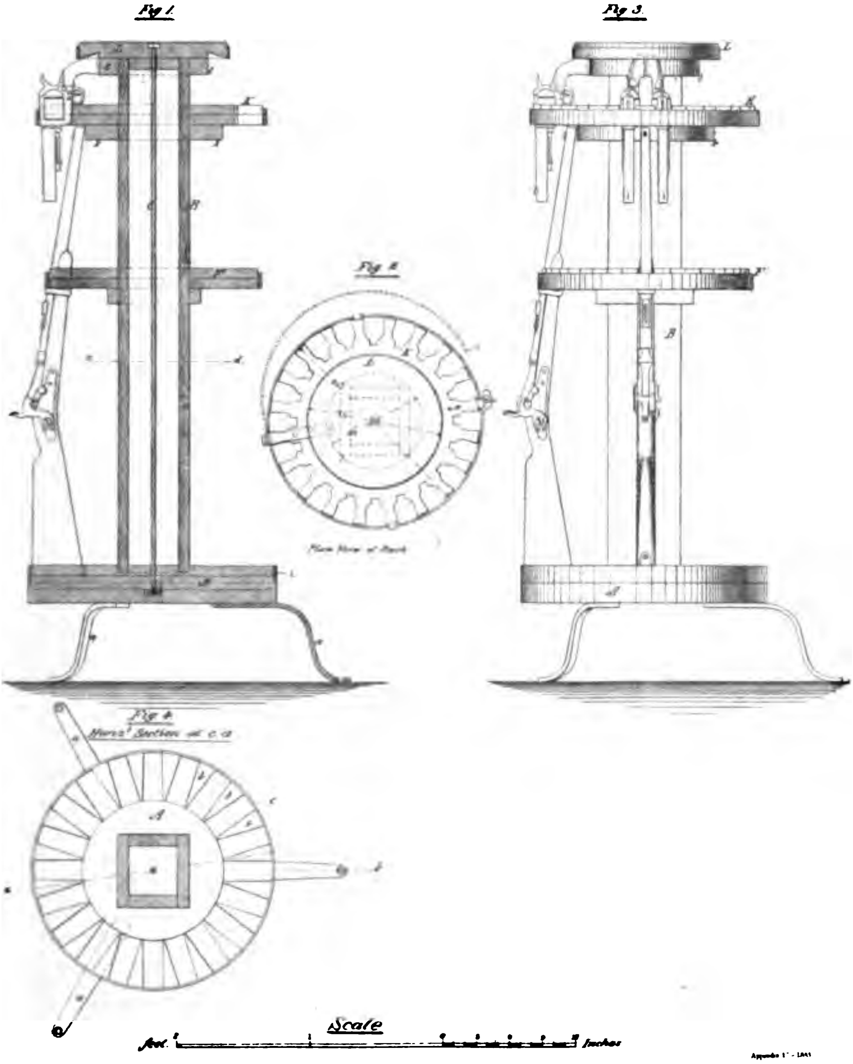


Rifle Arm-Rack.

Scale.

Appendix 17 – 1883

Carbine & Revolver Arm Rack (combined)



Appendix 1 - 1881

Revolver Arm Rack

for attachment to old pattern Carbine Racks now in service

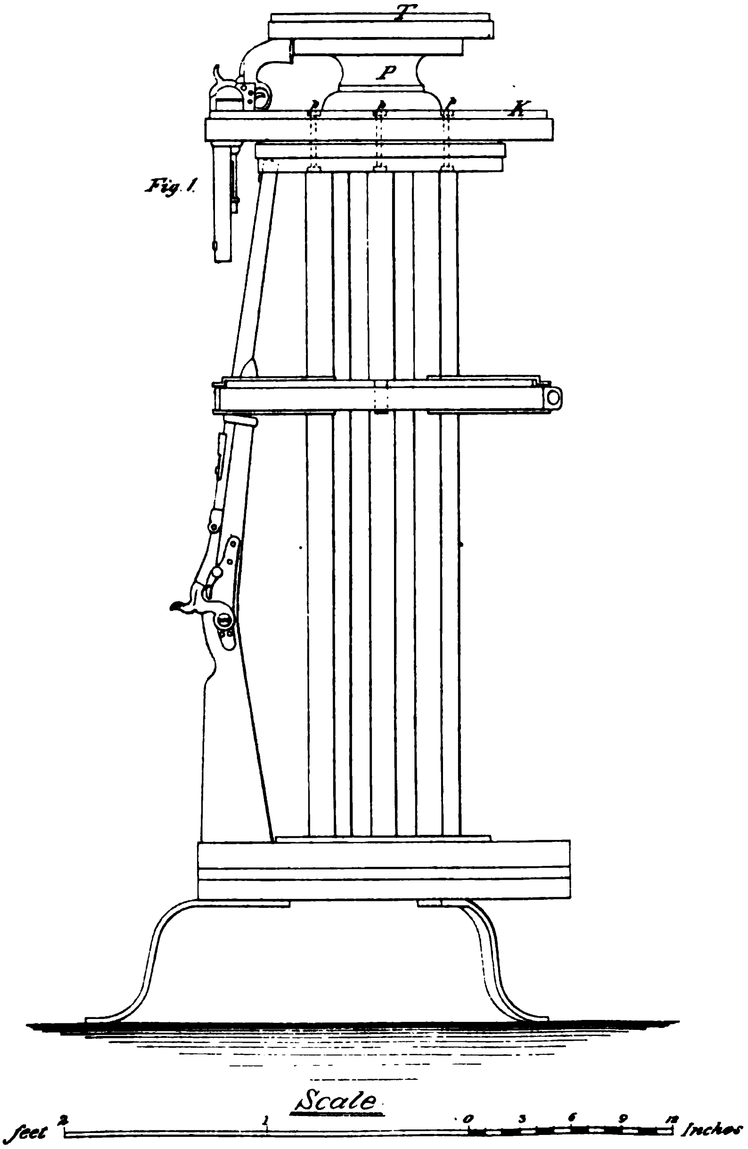


Fig. 1.

Appendix 17—1883.

APPENDIX 18.

IMPROVED CAPSTAN.

BY CAPT. HENRY METCALFE, ORDNANCE DEPARTMENT.

(1 plate.)

BENICIA ARSENAL, CAL., *March* 3, 1883.

SIR: In accordance with your instructions I have the honor to submit the following description of the improved capstan recently made here for issue to Fort Winfield Scott; reference being had to the drawing herewith.

The principal feature is the cast-iron head, with four tangential sockets for the bars, which fits on a square tenon formed on the upper end of the barrel, like the head of a wrench of which the bars form the handles. Owing to the reciprocally formed tapers given to the interior of this head, and to the exterior of the tenon on which it fits, the two contiguous surfaces will always be in close contact, in spite of shrinkage and wear. The head will therefore act like a band to bind the barrel together and keep it from splitting. It will be observed that the usual mortises cut through an enlargement of the barrel for the insertion of the bars have a directly opposite effect, tending to split the barrel on the application of the strain to which they are subjected in use.

Fig.1.
Moment–102.4

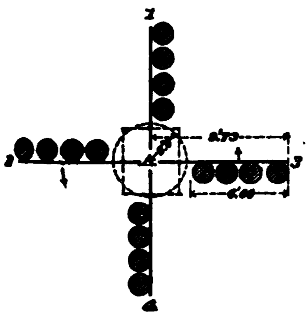


Fig.2.
Moment–302.72

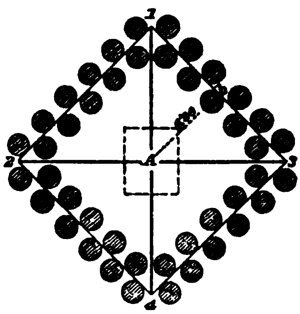
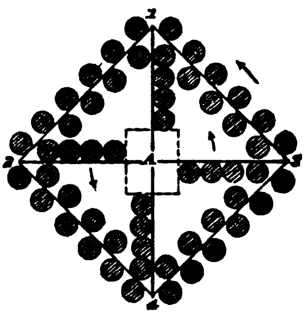


Fig.3.
Moment–368.72



The sockets in the cast-iron head are arranged tangentially, so as to increase the bearing of the bars without unduly increasing the size of the head. This limits the number of bars somewhat, but easily permits the use of four at once—all that are needed.

The sockets are made to receive, with very slight fitting, the butt of an artillery field limber pole, or a maneuvering handspike. These poles are generally of well-seasoned stuff, are found available at many posts, are well adapted for size and shape to this purpose, and, being provided with an eye at the outer end, afford means of joining those in use on the capstan by means of a rope, as shown in the sketch below.

This arrangement permits not only an increase in the leverage of the power, but increases very greatly the space available for its application.

Let A be the centre of the capstan of which the frame is shown in dotted lines in plan. Let A 1, A 2, &c., be the capstan bars; owing to their overlapping they are but 9.73 feet long from the the center.

Now, owing to the projection of the frame and its braces, only about 7 feet of the outer end of each bar is available, giving room for four men, as shown, Fig. 1. Allowing 20 inches per man, they will take up 80 inches=6.66 feet, and work with a lever arm$=9.73-\frac{6.66}{2}=6.4$ feet. This will give for each bar a moment$=6.4\times4=25.6$, and for the whole apparatus a moment$=25.6\times4=102.4$ foot-men.

Now if, as shown in Fig. 2, the ends of the bars be joined by a rope 1, 2, 3, 4, and this rope be manned as shown, the lever arm for each set of men will be the semi-diagonal

$$Ab, \text{\&c.}=\frac{\sqrt{9.73^2\times2}}{2}=6.88$$

By actual trial I find that there is room enough for eleven men between 1 and 2, &c., giving for each set of men a moment$=6.88\times11=75.68$, and for the four bars$=75.68\times4=302.72$ foot-men.

On each bar there is room left, as shown in Fig. 3, for three more men, who have a mean lever arm of 5.5 feet and a moment of $5.5\times3=16.5$. These raise the total for each bar to $75.68+16.5=92.18$, and for the whole apparatus to $92.18\times4=368.72$ foot-men, more than 3½ times the power applied in the usual way shown in Fig. 1.

I regret that the device shown in Figs. 2 and 3 did not occur to me until after the completion of the capstan, for by increasing the dangerous section of the bars from 2.5×3 inches to 3.25^2 and by suitably changing the other parts I could have made the bars strong enough for the extreme application of the idea. As they are, it will take the full strength of over nine men so applied at the end of each bar to break it.

The Ordnance Manual gives, page 471, as the mean effort exerted per day of eight hours of a man pulling or pushing horizontally = 27 pounds. (This is taken at 35 pounds in all other books that I have seen.) Taking it at 27 pounds, remembering that the radius of the barrel of the capstan = 6½ inches ÷ 2 = 0.27 foot, and for safety limiting the number of men at work to the number, 9, which exerting *full* strength (of 50 pounds) could break the bars, we have for the resultant working pull on the rope leading from the capstan to the object—

$$\frac{4\times27\times9\times6.88}{0.27}=24{,}760 \text{ pounds} = 11 \text{ tons.}$$

Tiball's Manual gives this, page 237, as the extreme safe load for a 6-inch hemp rope, which is on page 244 given as the largest rope usually required for use with gins. The extreme pull which the strength of the bars would permit is about 20 tons. This would part a 10-inch cable, unless some other part of the capstan gave way first, which would probably be the case.

Supposing the men arranged as in Fig. 1, and exerting their full strength for a short time, with intervals for rest during the arrangement of the blocking about the gun, the total pull is raised to $102.4 \times 50 \div 0.27 = 18,960$ pounds, which with a purchase of five sheaves, consisting of one double and one treble block, would raise a 15-inch gun. (Tidball, page 237.) This would be more than a safe load for a 5-inch hemp rope or a 6-inch Manila rope. It seems enough for ordinary use.

The capstan was tested after completion by breaking with it an old 5-inch rope worn down to 4¾ girth, but still in good condition. With four men at each bar it parted where double rove through the ring of the shackle bars. The men were walking around quite easily, and said that they did not use half their strength. Nothing broke, but the iron stirrups at the end of the sills were drawn inward by the strain and slightly imbedded into the sills.

The cast-iron head, though so light, weighing only 31 pounds, is abundantly strong. Its weakest point—that on the diagonal of the mortise—is so fortified by the triangular web cast in between the sockets proper that the area of rupture at this point is 5 square inches, while the breaking force at the instant of rupture of the capstan bars is $=9$ (men) $\times 58.26$ pounds (see note 1) $\times$ 6.88 (feet) $\div$ 0.5 feet (the entrance of the bar into the socket, $= 7,215$ pounds $=1,443$ pounds per square inch, giving a factor of safety of 14 for cast iron.

All re-entrant angles in the casting are filled so as to diminish the shrinkage strain.

The lips at the mouth of the sockets are curved and set back slightly, so as to avoid bending the bars around a square corner while under strain. In fact, every part of the capstan appears abundantly strong, both by calculation and trial. The main difficulty will be in providing anchors firm enough to test its power.

I made for this purpose three spikes of 2-inch iron about 3 feet long, which should hold well in hard ground.

WEIGHTS.

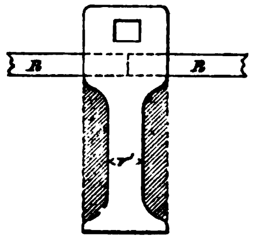
	Pounds.
Weight of detachable head	31
Weight of rest of capstan	226
Total weight	257
Weight of each bar	19¼

Two men can move the capstan easily, even to throwing it into a cart. The sled-like form of the sills also helps in moving it.

In my opinion this capstan possesses the following advantages over the old model, viz:

1. The use of four bars, singly in alteration or together, instead of a maximum of two.

Fig. 4.



2. Their having a full bearing instead of holding on by the ends.

3. The economy in not cutting away the greater part of the log, so as to diminish the lever arm of the resistance r', and yet get sufficient

bearing for the end of the bars in its head. (See sketch showing shaded parts cut away from the log.)

4. The advantage in having the four bars on the same level.

5. The enconomy in avoiding the mortising of two square holes for the butt ends of the bars through the head as shown in Fig. 4, and also

6. In avoiding the re-inforcing iron band shown in the prescribed pattern.

The iron casting weighing 31 pounds costs less than the other processes, and is at the same time stronger. The other parts are practically as before.

7. The advantage given by the use of four or more bars, whose ends are joined by a drag-rope.

8, 9. The advantage of the sledge shape given to the ends of the sills, and the strength gained by the position of the cross-brace, B (see drawing), which does not now intersect the sills at the point of weakness, caused by the entrance of the struts.

NOTE 1.—In the course of this investigation it became necessary to determine the maximum effort of a man in pulling or pushing horizontally, as a means of ascertaining the total power of the machine in raising weights at the instant of rupture of the weakest point, viz, that of the butt of the capstan bars. To do this, and also to determine the proper proportions of the bars, an old oaken artillery pole, field, of excellent material was fastened horizontally at the butt, and broken by the united effort of several men pulling on a rope fastened to its outer end The least number required to break it was found to be 13 men, pulling with a lever arm of 59 inches, the dangerous section being at the butt, and $=2.5$ inches (b) × 3 inches (d) estimated in the direction of the strain.

By the formula given, page 436 of the Ordnance Manual, this would give a value for the modulus of rupture in terms of men—

$$=S=\frac{lW}{bd^2}=\frac{59\times13}{2.5\times3^2}=34.09 \text{ men.}$$

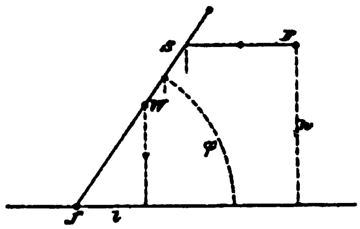
A value which was verified experimentally on another pole.

Now, equating this with the average value of the 14 kinds of American oak given (Ordnance Manual, pages 431, 432), where $S=1986$ pounds, we obtain as the maximum effort per man of the 13 men above, $1986\div34.09=58.26$ pounds per man.

If the oak broken by me were as good as the best Ohio oak for which S is given$=2890$ pounds, the above effort would be 84.77 pounds.

To be on the safe side, I have called it only 50 pounds in my previous discussion, except on page 9, where, for the same reason of safety, it was increased to 58.26 pounds.

This value appeared, not only to myself but to others, so small, the presumption being in most people's minds that a man should pull or push at least his own weight, that I was tempted to make the following brief analysis:



Let the line f $S=m$ represent a man with his feet well braced at f, and pushing horizontally from his shoulder, S, at a height, h, with a force in equilibrio with the force F, which sustains him. Let W be his center of gravity at the horizontal distance l, from his foothold, and let the ratio $\frac{fW}{fS}=a$.

Then equating moments—

$$Fh=Wl \text{ or } F=W\frac{l}{h} \quad . \; . \; . \; . \; . \; . \; . \; . \quad (1.)$$

but $l=fW\cos\varphi=am\cos\varphi$ and $h=m\sin\varphi$, substituting in equation (1)

$$F=W\frac{am\cos\varphi}{m\sin\varphi}=Wa\cot\varphi \quad . \; . \; . \; . \; . \; . \; . \quad (2.)$$

When a $\cot\varphi=1$, then $F=W$, and the man can push his own weight; after that the push will increase until he lies flat, when $\varphi=o$ and $\cot\varphi$ and F are both$=\infty$. Which is to say that this is the only position in which his strength has full play. Hitherto its only function has been to support him in a position in which his weight could act to the best advantage.

Supposing F to act horizontally, h will diminish as φ diminishes Under this supposition, in pushing one's own weight the value of φ will depend upon the build of the man or the relative positions of W and S; in other words, on the value of a. In my own case, I have determined it experimentally—

$$a=\frac{41}{58}=0.707$$

in the case of a very slender young man (Brough)—

$$a=\frac{39}{54}=0.704$$

Taking my own case and substituting in $a\cot\varphi=1, a=0.707$, we get $\cot\varphi=1.414=\cot 35^\circ 20'$. That is, that to push my own weight, 182 pounds, my body being held straight and my arms horizontal, my hands should be at about 33.5 inches from the floor. The lower I can put my hands and still hold myself straight the more I can push, hence the advantage when great power is required of keeping the bars near the ground.

The bars of this capstan are at 37 inches from the ground. By actual trial, I find that supporting myself against a bar of this height I am just able to hold myself straight at such an angle that a plumb-line hanging from my center of gravity will strike the ground 25.5 inches in front of my toes, my foothold being due to the friction between shoe leather and cocoa matting. This gives—

$$\cos\varphi=\frac{25.5}{41} \text{ and } \varphi=51^\circ 40'$$

In my case, it gives $F=125.4$ pounds. I am heavier, but probably no stronger, than the average working man. Supposing my build to be the same, our centers of gravity will be at heights proportional to our stature. Assuming him to be 68 inches tall and myself 71 inches, we have—

$$71 : 68 :: 41 : x=39.27$$

whence

$$l'=39.27 \qquad \cos\varphi=24''.42$$

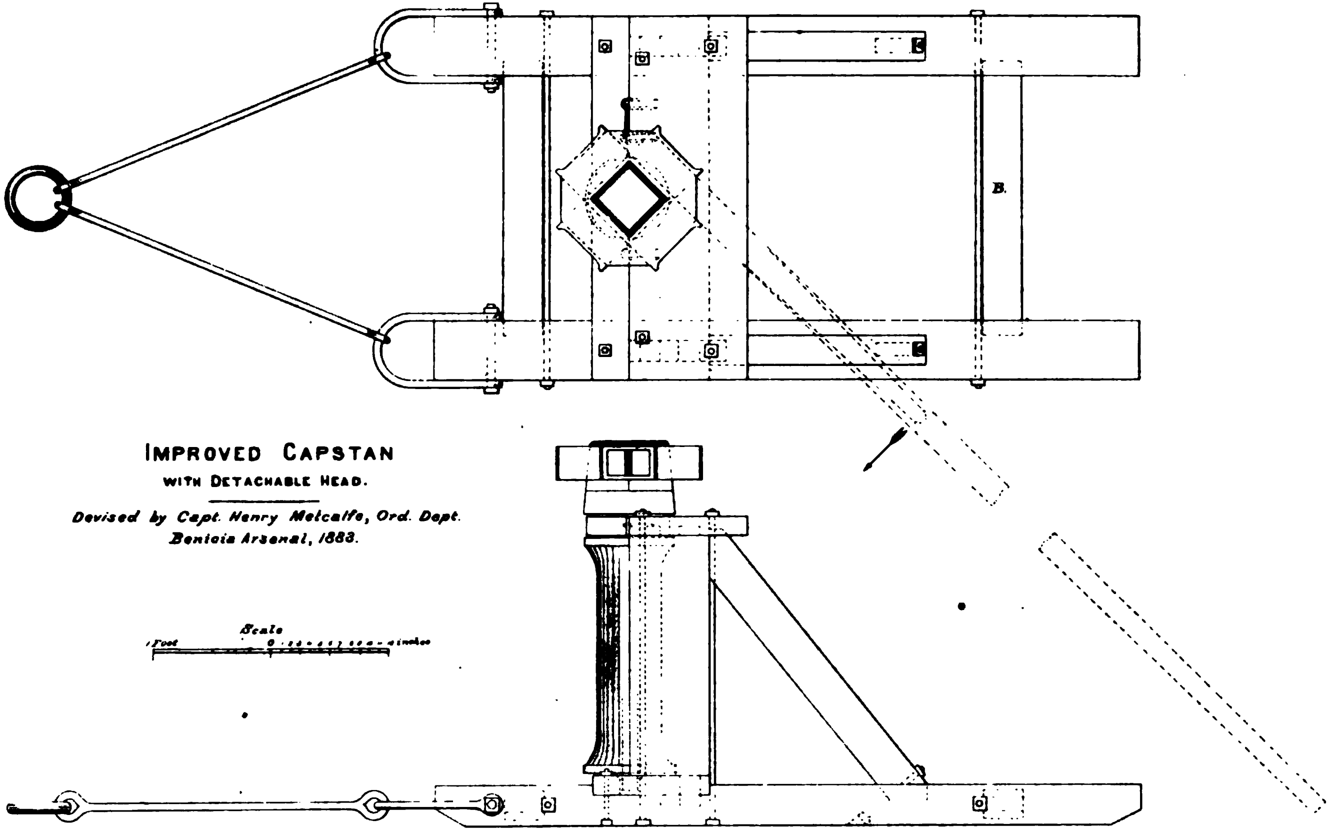
substituting in the equation—

$$F=W'\frac{l}{h}$$

and making $W'=150$ pounds, the average weight of men (see Ordnance Manual, page 455), we have $F'=99$ pounds, or say 100 pounds, which I should think about right, judging from the experimental breaking of the artillery pole, page 14.

The inclination of the body at this angle is such that I am doubtful whether much work could be performed, owing to the difficulty of moving the feet.

PLATE I.



IMPROVED CAPSTAN

WITH DETACHABLE HEAD.

Devised by Capt. Henry Metcalfe, Ord. Dept.
Benicia Arsenal, 1883.

APPENDIX 19.

A DESCRIPTION OF SOME OF THE IMPROVEMENTS INTRODUCED AT FRANKFORD ARSENAL DURING THE PRESENT FISCAL YEAR.

BY MAJ. S. C. LYFORD, ORDNANCE DEPARTMENT, COMMANDING.*

(12 plates.)

I.—THE SMITH & GOLDTHORP SYSTEM FOR MAKING ILLUMINATING GAS FROM PETROLEUM.
II.—THE FRANKFORD ARSENAL CARTRIDGE PRIMER.
III.—CANNON PRIMERS, FRICTION AND ELECTRIC.
IV.—THE AUTOGENIC PLUMBING APPARATUS.
V.—RUBBER STAMPS AND TYPES FOR MARKING PACKAGES OF STORES.

I.

THE SMITH & GOLDTHORP SYSTEM FOR MAKING ILLUMINATING GAS FROM PETROLEUM.

(1 plate.)

These gas works were put in operation at this arsenal in October, 1882, and have been in use since that time without interruption.

The manufacturers, in their printed circular, make the following statements regarding the apparatus and its product, which have been fully substantiated by the records of its operation here during the past seven months:

> Petroleum gas is an extremely rich carbureted hydrogen, made by passing petroleum or any of its products (gasoline excepted) through a retort heated sufficiently high to transform the liquid into a permanent fixed gas.† Owing to its richness in carbon, this gas, when properly made, has about five times the illuminating power of good city coal gas, so that a jet or burner consuming 1 foot per hour supplies as much light as a burner consuming 5 feet of coal gas per hour.
>
> As will be seen from the description, the works are extremely simple, so much so that they can readily be operated by any man or boy of average intelligence. The parts are few in number and can be cheaply supplied, keeping expenses for repairs down to a minimum.
>
> The petroleum gas produced by our system is absolutely safe, both in its manufacture and use, no accidents having ever occurred in connection with it since its introduction.

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* Descriptive text by Mr. J. J. O'Reilly, subinspector of powder.

† To distinguish the pure petroleum gas from the mixture containing air, the word "vapor" is sometimes used in this paper for the former, and the word "gas" for the latter, it being the illuminant.

The petroleum gas or vapor is not condensable under ordinary conditions, nor is the mixture, both being fixed gases, as will be seen by the fact stated that so far the drip boxes have not required to be pumped out.

Among the special advantages cited are the following:

Reduced size of street mains.
Reduced size of gas meters.
There is no naphthaline to clog or close the pipes or burners.
The gas produced by our process is the only illuminating gas which does not condense or deteriorate on being subjected to intense cold or pressure.

The following analysis of the petroleum gas appears in a later circular of the firm:

Carbonic acid	0.46
Oxygen	1.10
Carbonic oxide	2.29
Heavy carbureted hydrogen and other illuminants, hydrogen, and nitrogen	96.15
	100.00

Also the following statement from an eminent engineer:

> The gas made by your apparatus being free from sulphur, nitrogen, ammonia, and carbonic acid, as found in the gas made from coal, needs no expensive scrubbers or washers, and thus vastly reduces the care or expense necessary to purify it, and is decidedly less deleterious to health when consumed in a close room.

The gas works at the Frankford Arsenal (see Plate I) consists of a gas holder of 3,000 cubic feet capacity, contained in a brickwork tank filled with water, in which the holder is suspended from a tripod framework, and supported by wire ropes and counterpoise weights.

The water in the tank is kept from freezing in cold weather by a jet of steam, which keeps the surface water above the freezing temperature. A water-pipe and hose are provided to replace the loss of water by evaporation from the tank.

Suitable inlet and outlet pipes with valves convey the gas respectively to and from the holder by connections with the generators and the distributing mains.

Duplicate generators are provided to guard against accident or injury to one. They may be operated singly or together, as desired, being entirely independent of each other.

The generator is a cast-iron furnace, lined with refractory clay tiles, containing ash-pit, grate, fire space, and four cast-iron retorts, as shown in section on Plate I.

The retorts are connected at their upper ends with pipes to convey the gas to the washing apparatus in rear of the furnace, and at their lower ends with pipes through which the oil is fed from a tank overhead, into which it is pumped from an underground storage tank as required.

The washers consist of two cast-iron boxes, provided with connections for pipe and filled with water, through which the gas passes on its way from the retorts to the holder; the effect being to cool the gas and separate any condensed products of the distillation of the oil. When the works are in operation the water in the washers is renewed by suitable inlet and outlet pipes, keeping it cool and at a constant level.

The residuum from the washers is conveyed to a barrel sunk in the ground, from which it is removed from time to time and used for disinfecting purposes or thrown away. When refined petroleum is used and retorts are properly heated, the quantity of residuum is very slight, not exceeding 1 per centum of the oil converted into gas.

Steam-pipes are provided to warm the building when the furnaces are not in operation and cleaning or repairing is to be done.

As originally constructed here, the furnace had an arch of fire-clay tities, with openings over the fire, through which it acted upon the retorts. Its effect was to allow the fire to act more directly upon some than upon other parts of the retorts, producing a slow and irregular heat. Shortly after the works were put in operation this arch was removed, exposing the whole surface of the retorts to the action of the fire, and enlarging the fire space to effect a more economical consumption of fuel. The change has proved a decided success, yielding a larger volume of vapor per unit of oil and fuel.

The oil thus far used, refined petroleum or crude benzine, has a gravity of about 50° Beaumé. It is delivered here in barrels at 6 cents per gallon. It is preferable to crude petroleum in giving less residuum, but if the crude oil could be delivered in bulk or tank cars by rail, it would be cheaper and equally satisfactory. The refined oil cannot be procured in bulk, and is therefore purchased in barrels; but these, when empty, are received back at their full value by the refiners.

Any product of petroleum, except that known as gasoline, may be used in these works, a choice depending mainly upon the facilities for obtaining a proper supply.

The most satisfactory fuel has been found in anthracite stove coal, the process requiring a bright, strong fire to raise and maintain a temperature of about 1,000° Fahrenheit in the retorts.

The introduction of this plant involves no change in existing mains, pipes, or fixtures, the burners only being a specialty supplied with the works. A holder already established for any other gas can be used for this without change.

Owing to the limited size of our holder (the capacity of which was underestimated by an error in the calculations made here prior to contracting for the works), the furnaces have been operated four or more times per week during the winter and spring, but with longer days and less nightly consumption it will not be necessary to operate them so often.

With another holder of equal or greater capacity, gas need not be made oftener than twice a week, and the cost of labor and fuel would be lessened; besides, it would afford means of regulating the pressure of supply to the burners, and facilitate the mixture of air with the petroleum vapor, rendered necessary with the burners now used.

The pure vapor is so rich in carbon that, to avoid a smoky flame from these burners, it requires to be mixed with air in proportions varying with the richness of the vapor, generally one volume of air to two of vapor, which perfectly controls this feature of the flame.

The air is introduced into the holder either before, after, or at intervals during the time of filling with vapor from the retorts, and time allowed for the two fluids to mingle.

With one holder for the pure vapor and another for the gas mixture, this operation would be greatly facilitated and the frequency of making gas reduced.*

The air is forced into the holder by means of a rotary blower, operated by a lever and crank, such as used for blacksmiths' forges.

Experiments are in progress, with every prospect of success, to perfect a burner which will burn the pure vapor without smoking. Such a burner, consuming not more than 0.75 cubic foot per hour, would render the mixture of air with the vapor unnecessary. The present burner is of the ordinary lava-tipped pattern, consuming 1.3 foot per hour. The flame is smaller but whiter, and of equal brilliancy with that of the nominal 5-foot-per-hour coal-gas burner.

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* Since this was written an additional gas-holder has been procured, having a capacity of 6,000 cubic feet, and a tank and connections for it are nearly completed

No chemical treatment of the vapor is required to purify it. The operations are cleanly, free from offensive odor in the building, and at a reasonable distance no indication of the presence of a gas-works can be detected by the sense of smell.

The contractor operated the plant for one day after its completion, at the same time instructing an enlisted man detailed to learn the process. This man has since operated the plant steadily without any difficulty whatever. This fact, in connection with its other advantages, should commend the system as one well adapted for military posts and other similar establishments.

The length of trial given it here, the unqualified success its record sets forth, together with its economy, certainty, simplicity, and durability, leave no doubt of its being one of the most, possibly the only, satisfactory system of gas production, on either a large or small scale, ever perfected.

The following detailed record of the operation of this plant during the past seven months gives all important data observed from day to day. As it stands it includes trials of several varieties of oil, fuel, and the variation in details of manipulation attending the acquisition of practical experience by the operative, a man of only moderate skill and intelligence, which may in a measure account for a variable amount of product. No correction has been made in the latter for the effect of varying daily temperature upon its volume, the amount of fuel burned or oil distilled, &c.; such refinements being deemed of less importance at present than a fair record, kept by the operative, of all fluctuations incidental to variations in material temperature and manipulation, upon a blank form prepared for the purpose, a sample of which is appended hereto.

The only casualty which occurred was the tilting, on one occasion, of the holder. Being too full, and suddenly exposed to the sun's heat at noontime, while the operative was absent at dinner, a puff of wind lifted one edge out of the water, and part of its contents escaped. It is now inclosed by a frame shed, which protects it from wind and sunshine and accidental sudden expansion of its contents.

The very low cost of repairs recorded does not include the alteration of the furnace, before mentioned, which was in the nature of an improvement not necessitated by wear and tear, and has more than paid for itself in an increased product of vapor per unit of oil and fuel consumed.

An examination of the daily records shows a gradual improvement, due to experience in manipulation and the selection and use of material.

Several different lots of the same oil, as well as samples of other varieties, have been used; but not enough data has yet been collected to warrant any opinion of their respective merits. The fuels tested were coke and coal.

The actual time consumed in making gas, as recorded, does not cover all necessary charges for labor; the building, works, and appliances must be cleaned and kept in good order. From seven months' experience, it is considered safe to charge one full day of ten hours for each time gas was made, including the time recorded. The operative being an enlisted man, his time has cost less than the rate charged; but to provide a margin for contingencies the rate of $1.50 per day has been charged for labor.

Hence, for the period covered by the record, the gross cost of the gas may be estimated as follows:

From the record we have—

Number of times gas was made	113
Quantity of illuminant produced, cubic feet	219, 152

DR.

Labor:	
113 days, making gas, &c., at $1.50	$169 50
Materials:	
19,965 pounds fuel consumed, at ¼ cent	49 91
2,646½ gallons of oil, distilled, at 6 cents	158 79
Sundries:	
Repairs	5 90
	384 10

CR.

219,152 cubic feet of illuminating gas, at $1.75 +	384 10

In comparing the cost of this gas with that of coal gas, it must be remembered that the nominal 5-foot-per-hour burner consumes in excess of that quantity of coal gas, and that its illumination is fully equaled by that of the petroleum gas burned at the rate of 1.3 foot per hour; and also that the latter is burned at a lower pressure than the former, and, consequently, the actual rate of its consumption is lower rather than higher than the nominal rate; we may safely take their rates of consumption for equal illumination as 5 is to 1. Upon this basis, the present price of coal gas being $1.90 per thousand cubic feet, and that of petroleum gas as given above, viz, $1.75, we find the relative cost for the same amount of light to be: Coal gas, $9.50; petroleum gas, $1.75, or a little more than 18 per centum of the cost of coal gas. On the basis of light from one thousand cubic feet of gas, the comparative cost is: Coal gas, $1.90; petroleum gas, .34+. But, to provide a full margin for variations from the assumed rate of consumption in the burners, let the cost of petroleum gas be taken at 20 per centum, or one-fifth the cost of coal gas, and we find the cost of equal illumination to be: By coal gas, $1.90; by petroleum gas, $\frac{190}{5}$, =$0.38 for the same amount of light.

Estimating the saving effected to the United States thus far by the gas-works at this arsenal upon the last basis of cost, as compared with the cost of equal illumination from city coal gas, we have:

1,095,760 cubic feet of coal gas, at $1.90 per thousand	$2, 081 94
219,152 cubic feet of petroleum gas, at $1.75+ per thousand	384 10
Difference equals saving to the United States	1, 697 84

(Or more than one-half the cost of the gas-works established here.)

When the city gas was used the pressure and supply were inadequate, the light poor at its best, and the shops could not be operated for ten hours daily during the year. The drip-boxes on the mains required to be emptied of the condensations about four times a year. Since the introduction of this plant the shops have been operated steadily ten hours daily, with sufficient light, and the drip-boxes have not yet required to be emptied.

Statistics of gas manufacture, Frankford Arsenal, from October 9, 1882, *to April* 30, 1883.

Date.	Time of firing.	Fuel burned.	Oil distilled.	Vapor made.	Air added.	Remarks, (Inch on gauge of holder = 32 cubic feet.)
1882.	*h. m.*	*Pounds.*	*Gallons.*	*Inches.*	*Inches.*	
Oct. 9	6 00	300	35	51	10	Anthracite coal, small stove size, for fuel throughout the month.
10	7 30	194	15	30	6	
12	8 50	200	29	51	11	
14	5 30	170	19	39	10	
17	8 20	200	31	60	15	Oil, Quaker City, refined.
19	8 30	188	29	50	19	Stormy day; raining and cold; barometer, 29".84; fire hard to keep up.
21	9 25	277	22.5	45	15	Bright, clear day; furnace No. 1 worked badly, making no gas; furnace No. 2 worked well; barometer, 30".90.
23	5 45	250	17	31	11.5	Furnace No. 1 making gas, but not sending it into holder; requested contractor to correct the trouble.
26	10 30	220	None.	None.	None.	No gas intended to be made; testing furnace No. 1.
27	6 30	178	27	50	17	Furnace No. 1 all right, Mr. Smith having corrected the defect, which was caused by the overflow pipe in the washer being too long.
30	7 30	193	31	52	26	Furnace No. 1; barometer, 29".96; day cloudy and raining at times.
Nov. 2	7 30	189	30	56	27	
4	6 30	172	25	44	24	
7	6 30	Coal, 50 Coke, 78	31	55	33	
9	8 30	Coal, 75 Coke, 83.5	34	55	26	
11	6 50	176	33	54	26	
13	5 30	162.5	21	39.5	19.5	
14	4 40	Coal, 84 Coke, 25	19	32	16	
15	5 30	Coal, 97 Coke, 44	16	24.5	12.5	
16	4 10	Coal, 89.5 Coke, 40	16	26	13	
17	5 40	157.5	15	29	14.5	
19	5 25	185	29	47	23.5	
21	6 55	179	28	36	18	
23	6 00	179	30	46	23	
25	7 30	200	30	41	20.5	
27	7 40	Coal, 174 Coke, 75	25	35	17.5	
29	7 00	Coke, 183.5	30	48	24	
Dec. 1	5 30	Coal, 138.5 Coke, 50	23	40	20	
3	8 05	Coal, 175 Coke, 50	33	42	31	
5	6 45	183	37	52	26	
6	5 35	161.5	20	33	16.5	
7	6 00	Coal, 150 Coke, 25	30	42	21	
8	7 15	210	21	30	15	
9	4 45	163	21	33	16.5	
11	7 40	209	31	47	23.5	
12	4 43	167.5	20	34	17	
13	6 10	178	26	38	19	
14	4 45	162.5	21	36	18	
15	6 00	172	17	34	17	
16	5 45	177	25	37	18.5	
18	7 40	216	41	41	20.5	
19	4 40	150	23	29	14.5	
21	7 30	202.5	45	47.5	26.5	
22	6 00	169	30	30	16.5	
24	6 30	182	28	40.5	22.5	
26	5 30	179.5	20	31.5	17.5	
28	8 45	200	*20 †10	51	28	20 gallons Standard Company's oil (experimental) made 59.4 cubic feet of vapor per gallon.
30	8 15	210	41	55	30	
1883.						
Jan. 2	7 40	179	33	55	30.5	
3	6 15	180	20	30	16.5	
4	6 00	193	18	32	18.5	
5	6 00	170	24	36	20	
6	5 15	169	20	31.5	17.5	
8	6 30	193.5	30	47	26.5	
9	5 55	170	21	34	19	
10	5 30	165	23	36	20	

* Standard.

Quaker City.

Statistics of gas manufacture, Frankford Arsenal, &c.—Continued.

Date.	Time of firing.	Fuel burned.	Oil distilled.	Vapor made.	Air added.	Remarks. (Inch on gauge of holder=32 cubic feet.)
1883.	*h. m.*	*Pounds.*	*Gallons.*	*Inches.*	*Inches.*	
Jan. 11	5 25	168.5	21	34.5	19	
12	5 10	174	20	36	20	
13	5 20	156	20	36	20	
15	6 25	188	30	48	27	
16	6 00	155	18	29.5	16.5	
18	6 15	178	30	50	28	
20	8 15	190	31	51.5	29	
23	6 30	192.5	32	48	27	
25	6 45	190.5	28	43	24	
27	8 00	200	38	50	28	
29	7 15	203	29	38	21	
30	5 45	175	20	32	18.5	
31	7 30	206	36	28	15.5	20 gallons refuse oil used.
Feb. 1	5 15	168	18	29.5	16.5	
2	6 15	159	15	30	16.5	
3	5 45	167.5	16	30	16.5	
5	8 30	210	27	49	27	
6	6 15	169	16	30	16.5	
7	6 00	165	17	30	16.5	
8	5 25	150	14	27	15	
9	5 00	150	14	28	15.5	
10	5 45	164	16	29	16.5	
12	7 00	192.5	25	48	27	
13	5 00	145	14	26	14.5	
15	8 30	182	27	47	26	
17	7 45	192	25	40.5	22.5	
19	5 35	168	20	36	20	
22	7 15	186.5	24	43	24	
26	7 30	190	28	51	28	
27	6 00	173	20	36	20	
Mar. 1	8 15	218	24	40.5	22.5	
3	5 15	164	22	40.5	22.5	
5	7 00	166	36	42	24	
7	4 35	150	18	42	23.5	
9	5 10	166	22	44	25.5	
11	5 15	150	23	43	24	
13	4 30	150	17	40	22.5	
15	5 50	143.5	20	38	21.5	Holder capsized by wind and contents lost; air introduced before gas making began.
15	3 40	150	15	31	17.5	
16	4 35	135	20	41	23	
19	6 15	145	22	41.5	23	
21	4 00	131.5	18	36.5	20.5	
24	4 55	142.5	21	43	25	Repairs cost $5.90.
27	4 35	158	18	44	25	
29	4 25	162	17	38.5	21.5	
31	3 45	150	13	36.5	20.5	
Apr. 2	4 10	150	17	40	22	
4	4 00	150	18	41.5	23.5	
6	4 15	150	15	39	22	
8	4 10	150	13	39.5	22.5	
10	4 15	150	15	36	20	
12	3 55	150	14	37	20.5	
15	4 15	130	14	35.5	19.5	
17	4 30	159	16	45.5	25.5	
20	4 20	150	14	36	20	
23	4 15	150	15	40.5	22.5	
25	4 45	150	16	44	24.5	
29	5 15	170	20	49.5	27.5	Coal dirty.

Monthly summary of daily records, with cost of material, product, &c.

Months, 1882 and 1883.	Number of times gas was made.	Time of firing.		Fuel burned.	Oil consumed.	Vapor made.	Air added.	Gas mixture.	Cost of labor, at 15 cents per hour.
		h.	*m.*	*Pounds.*	*Galls.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	
October	10	84	20	2, 370	255. 5	14, 688	4, 496	19, 184	$12 65
November	16	101	50	2, 698	417	21, 376	10, 816	32, 192	15 28
December	21	133	50	3, 881	583	26, 352	13, 600	39, 952	20 08
January	21	133	40	3, 796	542	26, 432	14, 784	41, 216	20 06
February	17	108	45	2, 929. 5	336	19, 520	10, 832	30, 352	16 31
March	16	82	00	2, 481. 5	326	20, 544	11, 584	32, 128	12 30
April	12	52	05	1, 809	187	15, 488	8, 640	24, 128	7 81

Months, 1882 and 1883.	Cost of fuel, at ¼ cent per pound.	Cost of oil, at 6 cents per gallon.	Total cost of gas mixture.	Cost of gas mixture per 1,000 cubic feet.	Cost of repairs.	Vapor per gallon of oil.	Vapor per pound of fuel.
						Cu. ft.	*Cu. ft.*
October	$5 93	$15 33	$33 91	$1 80	....	57. 5	6. 2
November	6 75	25 02	47 05	1 50	....	51. 3	7. 9
December	9 70	34 98	64 76	1 70	....	45. 2	6. 8
January	9 49	32 52	62 07	1 50	....	48. 8	7. 0
February	7 32	20 16	43 79	1 40	....	58. 1	6. 6
March	6 20	19 56	38 06	1 20	$5 90	63. 0	8. 2
April	4. 52	11 32	23 65	1 00	....	82. 8	8. 5

(F. A. FORM NO. 32.)

Statistics of gas manufacture at the Frankford Arsenal.

Date.	Name of operative.	Firing.			Fuel.			Oil.			Hours worked.	Wages per hour.	Value of labor and material.	Gas.					Air.		Repairs.		Remarks. (Inch on gauge of holder=31.25 cubic feet of content.)
		Fires lighted.	Fires extinguished.	Time of combustion.	Kind used.	Quantity used.	Value.	Name of oil.	Gallons used.	Value.				Content of holder.		Quantity made.	Cost per 1,000 cubic feet.	Pressure on mains.	Quantity introduced.	Percentage.	Character.	Cost.	
														Before.	After.								
						Lbs.								*Ins.*	*Ins.*	*Ins.*			*Ins.*				

II.

THE FRANKFORD ARSENAL CARTRIDGE PRIMER.*

(7 plates.)

This primer is designed and manufactured as a component of the solid head, reloading cartridge, which has a pocket, formed in the exterior of the base of the shell, to receive and securely hold the primer.

It is essentially a revival of the percussion cap, which served for many years as an adjunct to muzzle-loading small-arms, and now, modified in its form, construction, and application, fills an equally important purpose in the modern breech-loader, being an integral part of the cartridge, instead of a detached auxiliary to the arm.

It consists of a copper cap, containing a pellet of fulminating composition, protected by a disk of tinfoil, and a copper anvil, so formed as to permit the flame from the fulminating composition to pass, through a vent in the pocket of the cartridge-shell, to the powder charge, and at the same time afford resistance to the blow of the firing-pin of the arm, which explodes the fulminate.

The primer cap is formed, charged, and dried before the anvil is inserted. When the two are assembled the complete primer is ready for insertion in the pocket of the shell, prior to loading the latter with powder and bullet.

The materials entering into its composition are as follows:

Materials.	Components.
Sheet cartridge-copper	Primer cap.
Fulminating composition	
Tinfoil	
Cartridge copper wire	Primer anvil.

The sheet cartridge-copper is received from the manufacturers in the form of a ribbon, about 50 feet long, from 0.36 to 0.37 inch wide, and from 0.025 to 0.027 inch thick, coiled for automatic feeding to the machine which forms the caps.

The blanks for the caps are cut from the sheet-metal ribbon as disks and formed into caps by a double-action press (see Plate II), the disk being cut by a die and hollow punch, and pushed through the die to form a cap by another punch following it down through the hollow one. This machine is automatic, requiring attention only when a ribbon is cut up and is to be replaced with another. The skeleton or scrap ribbon is also cut into short pieces by the machine, to facilitate its packing and return as scrap to the manufacturer.

The metal ribbon having been oiled to facilitate the formation of the caps, they must be washed in an alkaline solution to remove every trace of oil, which, if present, would destroy the fulminate.

After washing and drying, the caps are varnished on the interior surface of the base, to protect the fulminate from injurious chemical action with the metal, and to assist in attaching and sealing it in place. A solution of gum shellac in alcohol, four pounds of the former to one gallon of the latter, constitutes the varnish used.

The varnishing machine (see Plate III) consists of an iron bed-plate and two uprights, upon which a cross-head, carrying a gang of wire pins, moves vertically over a vessel containing the varnish. Just above the varnish-pan the bed-plate is grooved to receive and adjust accurately, under the gang pins, a plate containing the caps, in receptacles arranged in rows corresponding to the pins.

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*The machines for the manufacture of cartridge primers were procured from the Union Metallic Cartridge Company, of Bridgeport, Conn.

The plate is filled by shaking it, with a handful of caps placed over the receptacles, with a horizontal motion. The caps settle into the receptacles, open end up generally, and the surplus caps are shaken off. The filled plate is inspected, and any caps requiring it are reversed by the aid of a forceps.

The caps remain in the plate until they are charged, inspected, and ready for removal to the drying-room. A plate holds 326 caps, and a tally is kept of each plateful, to keep account of the number of caps completed.

In varnishing, the ends of the pins are made to dip into the varnish by lowering the cross-head to a stop. When it is lifted each pin carries a drop of varnish. The plate of caps is pushed into the groove in the bed-plate, the cross head is lowered until the pins touch the caps, and then raised, leaving a drop of varnish in each cap.

The plate of caps is withdrawn and laid for a few minutes upon the heater, which consists of an iron plate heated by steam pipes under it to a temperature of about 200° Fahrenheit, the object being to dry the varnish.

The plate of caps is removed to the cooler, which is an iron plate cooled by contact with water on its under surface. By the reduction of their temperature the caps may be safely charged without further delay.

The fulminate composition consists of—

Moist fulminate of mercury	6	pounds.
Powdered chlorate of potash	1.75	pounds.
Ground glass crystals	1.66	pounds.
Mucilage	14	fluid ounces.

The preparation of the fulminate of mercury is fully described on page 300, Ordnance Manual, 1861, except that aquafortis of the same specific gravity is used instead of nitric acid, the former being the commercial nitric acid and less expensive.

The ground glass is sifted between bolting cloths of 100 and 160 meshes per linear inch, to remove coarser and finer particles.

The mucilage is prepared as follows: Two ounces of gum tragacanth are soaked in six pints of water, to which a few drops of tincture of cloves are added to prevent souring. After two or three days the paste is strained through a cloth to remove lumps and foreign matter. Two ounces of powdered gum arabic are dissolved in half a pint of cold water, and after standing about three hours, strained through a cloth. The dissolved gums are mixed together, and, if necessary, thinned with water.

Owing to its liability to sour in warm weather, the mucilage should be made only in such quantities as can be used before it spoils.

The moist fulminate is well drained of its water, spread upon a board, and rolled out into a thin sheet, like pastry. The dry chlorate of potash and glass dust are spread evenly over, and thoroughly incorporated with it, by means of a wooden rolling-pin and a spatula, using care not to allow any of it to become scattered and dry. The mucilage is next added, and the whole mass well stirred and mixed, after which it is placed in a delf bowl and the latter covered with a damp cloth. If too moist, it is left spread out a short time until it has the consistency of a stiff paste.

The charging machine (see Plate IV) consists of a rectangular iron bed-plate 18 by 20 inches. At one edge is a groove to receive the plate of caps from the cooler. Near the inner edge of this groove a plate, perforated with holes corresponding to the caps, is hinged to the bed-plate, to measure and convey the charges to the caps. A heap of the fulminate is placed upon the bed-plate, convenient to the charge-plate. A piece of stout paper is laid upon the bed-plate, under the charge-plate. A portion of the fulminate is taken from the heap, pressed into the holes in the charge-plate, and the surplus scraped off with a wooden tool and returned to the heap. The paper is drawn a little from under the charge-plate, while pressing upon the latter, to "set" the charges in the holes. The charge-plate is rotated on its hinge until it rests over the caps. A block of iron containing pins corresponding to the holes in the charge-plate is hinged to the bed-plate at the outer side of the groove containing the plate of caps. When not in use it rests against inclined supports. This block is next rotated on its hinge until it presses the charges through the holes in the charge-plate into the cap. The block and charge-plate are swung back and the plate of caps withdrawn and carried to the foiling machine.

The charge, of cylindrical form, occupies about one-third the diameter in the center of the bottom of the cap, and it is desirable to avoid spreading or disturbing it, in order that the tinfoil disk may touch and adhere to the cap all around it.

The tinfoil is procured in strips about 150 feet long, 2.25 inches wide, and from 0.003 to 0.0035 inch thick. It is cut into strips about 4 feet long for convenience in handling and feeding to the machine. This short strip is laid flat upon a table, and its upper surface is coated with shellac varnish, after which it is laid aside to dry. A number of strips having been thus prepared, one at a time is taken and again coated with a thinner shellac varnish immediately before feeding it to the foiling machine. The last coat of varnish softens and combines with the first and facilitates the attachment of the edge of the tinfoil disk to the varnished surface of the bottom of the cap around the charge.

The foiling machine (see Plate V) is a single-action press arranged to receive and move horizontally the plate of caps under a gang of punches and dies. The strip of foil is fed between these tools, and by them cut into disks. The punches press the disks through the dies into the caps, and the ends of the punches, being concave, press the edges of the disks around the charges against the bottoms of the caps, and at the same time the punch gives the charge a uniform conical shape, that its height may permit the insertion of the anvil far enough into the cap to prevent premature explosion in this operation and that of inserting the completed primer in the pocket of the shell, while leaving no unnecessary space between the anvil and the apex of the charge.

The caps are next shaken out of the plates into trays having woven brass-wire bottoms, in which they are removed to the drying-room (see Plate VI), where they remain for six or eight weeks. The room is kept at a temperature of about 100° Fahrenheit, and by suitable ventilation its atmosphere is kept in motion and gradually renewed.

This process is necessary to dry and harden the charge. At first sight it would seem to impair the sealing between the tinfoil disk and the base of the cap, for that is the only avenue of escape for the moisture of the charge; but it is probable that the temperature slowly dries the charge and keeps the varnish soft enough to renew the sealing at such points as it may be temporarily opened by the escaping moisture.

A comparison of the waterproof quality of caps dried in this slow

The more important of the machines and tools are the charging machine, the foiling machine, and their auxiliary tools, which are illustrated in the accompanying plates.

The charging machine (see Plate IX) is a tin-lined wooden hopper, having two supports across its upper end, serving to hold a rack containing the primers to be charged and the charging tool. A drawer under its lower end receives the overflow of powder from the charging tool. "Rifle" powder is used to charge the primers, each charge containing about 7 grains by weight.

Before charging, both varieties of primers are "primed," the friction primer, with its serrated wire, packed in friction composition, of which the tersulphide of antimony (sulphuret) is the basis; and the electric primer, with its bridge of platinum wire and copper connecting wires, a small wisp of gun-cotton being attached to the bridge.

For the charging and foiling operations the primers are assembled in a metal rack which has dowels to receive and adjust the charging tool over the open ends of the primers.

The charging tool consists of two plates held together, but susceptible of a slight movement of the upper upon the lower one. The upper one has tapered holes and the lower one cylindrical holes, corresponding to the primers in the rack. The upper one measures the charges, and its movement, by means of a cam and thumb-nut, upon the lower one, opens or closes the lower end of the tapered charge holes.

The charging tool, having the charge holes closed at the bottom by its motion on the lower plate, is placed upon the rack of primers. A quantity of powder is poured over the charge holes, filling them, and the surplus is stroked off with a straight edge.

The upper plate is now moved so as to empty the charges, through the holes in the lower plate, into the primers. A slight shock or jar settles the powder in the primers, the charging tool is lifted off, and the rack passed to the foiling machine.

The foiling machine (see Plate X) is a double-action press, arranged to feed the rack of primers horizontally under a gang of punches and dies. The tin-foil in the form of a coiled ribbon about 1.25 inch wide and 0.004 inch thick, is fed in between the punches and dies. These cut and form the tin-foil cup, in the usual way, and the cupping punch presses it down through the die into the end of the primer, at the same time slightly compressing the charge of powder. The tin-foil cup is subsequently secured by means of shellac varnish.

The cartridge copper is a more durable metal than brass, which is liable to rot and break easily after long storage or exposure to the atmosphere.

The tin-foil stopper is more permanent under wide variations of temperature than the wax one. At high temperatures the latter was sometimes softened and forced out by the expansion of the air, &c., confined in the primer.

The charging machine insures a full charge of powder in every primer, which was not made certain by the old method of charging them by hand.

The foiling machine effectually closes the charge in the primer until it is exploded.*

It is not improbable that many reported failures of both varieties of primers may have been due to an insufficient charge, if not to its entire

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*The charging machine for cannon primers was designed at this arsenal, and the foiling machine is a modification of that used for cartridge primers.

takes up the color from the spongy gelatine and holds it ready for contact with the stamp.

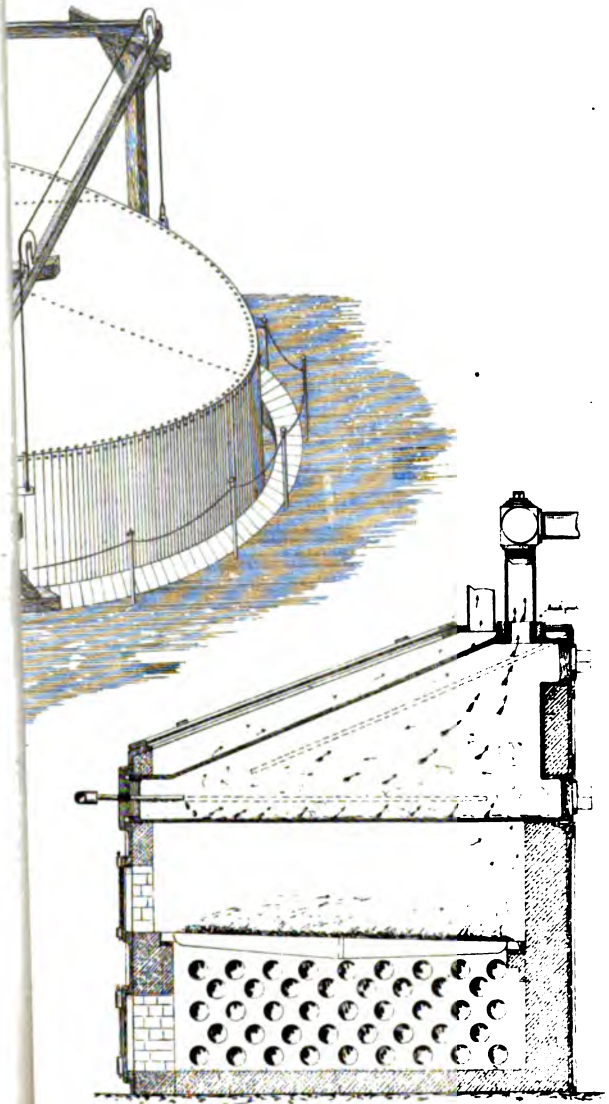
The simplicity and economy of rubber stamps and types and the neat appearance of their work commend them for use in preference to stencils. Their use involves no special skill on the part of the operator—in fact, much less than with stencils—and the sharpness of their impressions permits the use of smaller characters, giving a distinctness equal to larger ones made with stencils.

Any types or designs composed of printing materials, wood-cuts, &c., can be readily duplicated in sheet rubber directly from plaster casts, but the electrotype is more economical for permanent designs requiring frequent reproduction in rubber.

With reasonably fair usage and proper ink having no destructive action upon the rubber, the stamps are very durable and seldom require renewal.

Other applications of the rubber stamps are contemplated, with prospects of success and consequent economy, together with their other advantages.

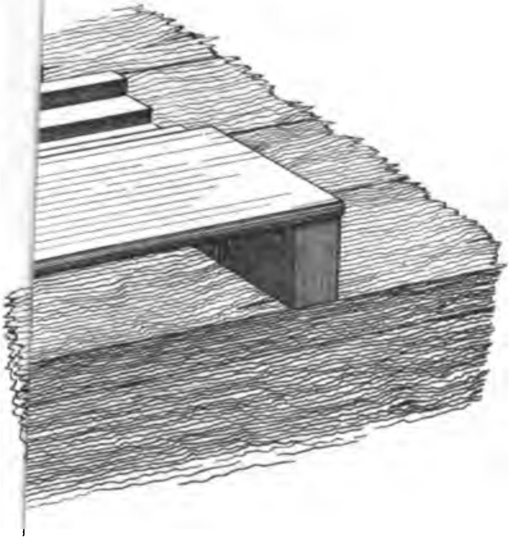
PLATE I.



Vertical Section of Furnace & retort through Axis of latter.

Appendix 19. [illegible]

PLATE X.



Appendix 19—1883.

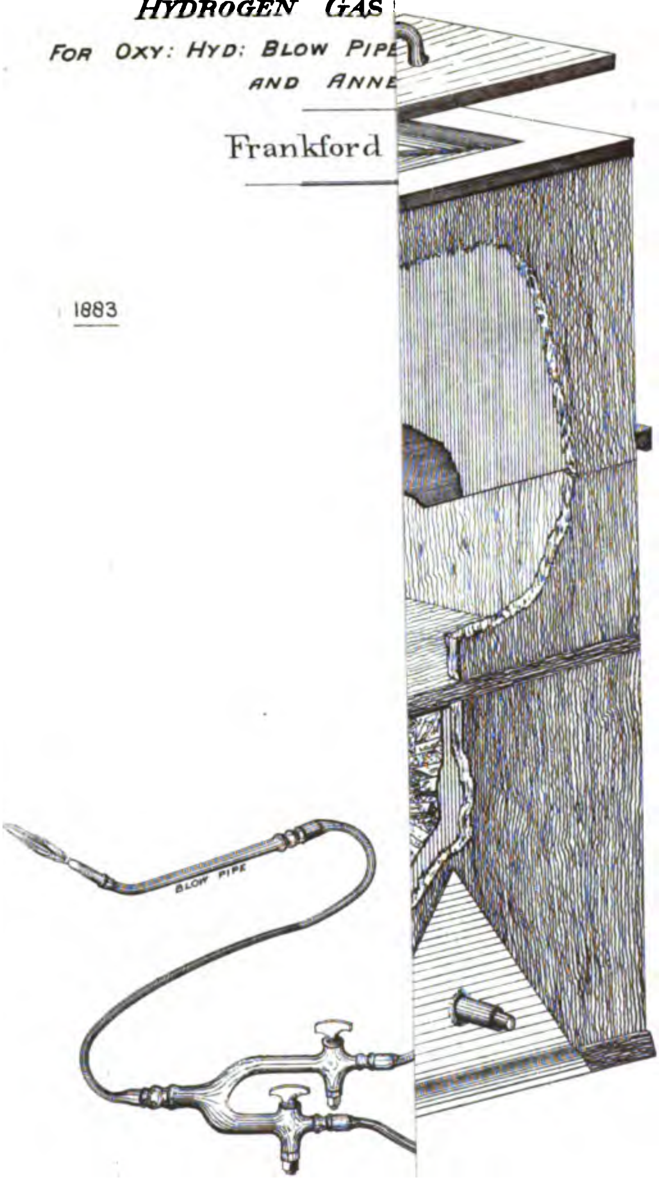
PLATE XI.

HYDROGEN GAS

FOR OXY: HYD: BLOW PIPE
AND ANNE

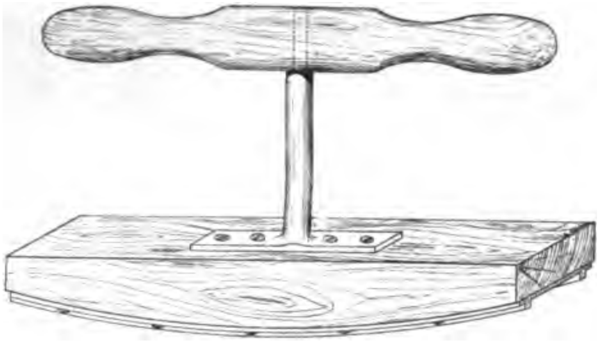
Frankford

1883

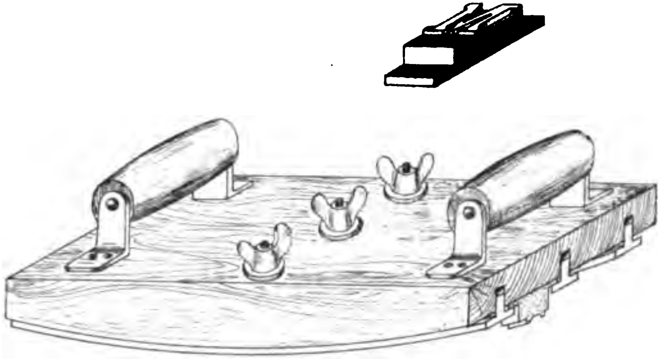


Appendix 19—1883.

PLATE XII.



Sheet. Rubber Stamp.



Type Rubber Stamp.

U. S. Frankford Arsenal.

Appendix 19—1883.

APPENDIX 20.

HEADLESS SHELL EXTRACTOR FOR SPRINGFIELD RIFLE AND CARBINE.

DEVISED BY LIEUT. COL. A. R. BUFFINGTON.

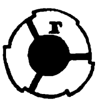


Fig. 1

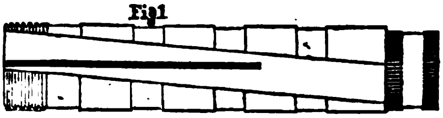


Fig. 2.

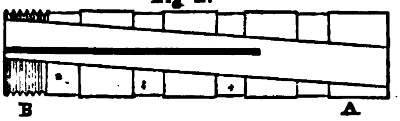
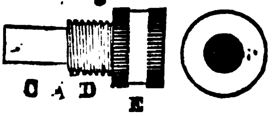


Fig. 3



DESCRIPTION.

Consists of two parts of tempered steel, the extractor proper, Fig. 2, and small cylindrical drift, Fig. 3, for setting out the prongs, carried screwed into end A of extractor. Fig. 1 shows them together as they should be habitually kept and used for all extractions from the *bore* of the rifle.

The extractor proper is a hollow cylinder, rifled on the exterior to correspond with the rifling of the rifle barrel, with four transverse grooves to the depth of the rifling. Inside it is shaped at the prong end to receive the point C of drift and permit a limited expansion; at the other end it is tapped for the screw thread D of the drift. Three cuts longitudinally divide one end into three prongs, F, around which is a screw thread B, for taking hold of the shell *when in the chamber.*

The drift is a cylindrical piece of three diameters: the head E, thread D, and point C. The head is sufficiently small to allow it to pass freely through the bore; a cavity, G, in it prevents injury to firing-pin. The thread secures it to extractor. The point, when driven between the prongs of extractor as far as the construction permits, sets them out sufficiently to remove a shell, but not far enough to touch the walls when passed into the empty chamber.

USE.

The parts should be kept screwed together and never separated for use, in *any case*, until after passing it as a whole—solid (drift) end foremost through the bore from the muzzle—and failing to remove the shell. Passing it thus—using larger end of rammer to do so—will remove any shell or part of shell in the bore, or slightly protruding into it from the chamber.

Failing to do so, unscrew the drift; insert the extractor, prong end foremost, into the chamber; close the breech; pass the drift, point foremost, into the bore at the muzzle; follow it with the larger end of rammer; drive it gently "home" between the prongs of extractor; open the breech and drive out the shell.

After the shell is out, the two parts either separate or can be separated by the fingers, and the shell removed from extractor. The prongs being in the mouth of the chamber, the point of drift invariably enters between them if the drift be passed through the bore as directed.

In case of accumulated or hardened fouling or dirt in the bore, the extractor as a whole, as directed, may be passed through it with advantage either as a preliminary to cleaning or wiping, or to remove the *cause* of swelled and burst barrels. In the latter case it should be used just before each shot when at the target, or as often as convenient when hunting or in battle.

APPENDIX 21.

REPORT ON BRUSH MATERIAL AND THE MANUFACTURE OF BRUSHES.

BY CAPT. A. L. VARNEY, ORDNANCE DEPARTMENT.

(41 plates.)

WATERVLIET ARSENAL,
West Troy, N. Y., September 15, 1883.

Lieut. Col. A. MORDECAI,
Commanding Watervliet Arsenal:

SIR: I have the honor to submit herewith a report embodying such information as I have been able to gather bearing upon the sources, description, preparation, &c., of brush material, and upon the manufacture of brushes.

The subject of quality and relative cost of raw material first prompted investigation with a view to determining, if possible, the best means of procuring horse-brushes for the Army; whether by supplying materials and paying for manufacture, or by purchase of finished brushes. The soon-discovered liability of the Government to suffer fraud and extortion by both means, led to the conviction that a more thorough knowledge of the bristle trade and of brush manufacture than could be gathered from sources near at hand was indispensably necessary for proper selection of stock and intelligent inspection of horse-brushes when purchased "ready-made." Pursuant to this conviction, the authority of the Chief of Ordnance, and your letter of instructions of May 8, 1882, I visited Boston, Providence, and New York City, to push my inquiries among bristle merchants, manufacturers of brush fiber, and the city libraries. Very little could be learned from books, but the amount of information obtained from other sources added interest to the subject, gave further conviction of its importance to the Department, and induced an enlargement of the scope of the original design, so as to include, in a superficial way, the whole subject of brush manufacture.

Finally, for reasons set forth in the report, it was recommended that the Department undertake the manufacture, not only of horse-brushes, but of all other varieties used in the military service.

The wisdom of the recommendation seems to be confirmed by the success with which it has been put into execution with reference to horse-brushes, and the satisfactory prosecution of the work for nearly eight months at this arsenal.

Very respectfully, your obedient servant,

A. L. VARNEY,
Captain of Ordnance.

[First indorsement.]

WATERVLIET ARSENAL,
September 18, 1883.

Respectfully forwarded to the Chief of Ordnance, U. S. A., with the recommendation that this letter and the accompanying report be published for the information of officers of the Ordnance Department.

The report embraces much matter that cannot be found in print, and Captain Varney deserves much credit for the perseverance and labor he has devoted to the subject.

A report upon the manufacture of horse-brushes at this arsenal and upon the inspection of such brushes for the Ordnance Department will be submitted hereafter.

A. MORDECAI,
Lieutenant-Colonel of Ordnance,
Commanding.

REPORT ON BRISTLES, BRUSH FIBER AND BRUSHES, WITH ESPECIAL REFERENCE TO BRUSHES USED IN THE MILITARY SERVICE OF THE UNITED STATES.

PART I.—BRISTLES.

Of the materials used by the brush-maker, bristles form, by far, the most important item. For such uses they possess qualities which render them superior to all other known substances. They are described as a thick, glossy kind of hair, or elongated epidermic appendages analgous to the feathers of birds and the scales of reptiles. The name is often applied to the quills of porcupines, and the mustaches or whiskers of cats, seals, &c., but more generally to the hair with which swine are covered. Hogs' bristles are hard, transparent, horny substances, of a prismatic or nearly cylindrical figure, consisting of roots from which the hair is developed, and shafts or stems continuous with them. The outer extremities, usually split into two or more parts, are, in brush-makers' parlance, denominated "*flags*."

The stem of the bristle, like that of other hair, is composed of a horny integument of minute imbricated scales, with free ends toward the flag, a softer pith or medullary substance in the center, and an intermediate fibrous layer, constituting two-thirds of the bulk of the hair.

By some authorities the two interior substances are classed together as medullary. Two essential parts, the cortex, or investing coat of scales, and the medulla or pith, are, however, found in the hairs of all animals, notwithstanding wide differences of appearance, ranging from the fur of the seal and mole to the bristles of the hog, the quills of the porcupine, and even the horn of the rhinoceros.

Bristles are hard, stiff, and elastic to a remarkable degree, and of all animal products are the least liable to spontaneous decomposition. They are practically insoluble in water, even at a high temperature; but are decomposed in chlorine gas, and become a soft glutinous mass. In chlorine water they are unchanged except being deprived of more or less coloring matter. Prolonged exposure to the action of sulphurous acid gas also bleaches them without other preceptible effect. Though tenacious of their natural hues, they repel artificial colors, and can only be dyed with difficulty. A preliminary steeping for twelve hours in lime-water will prepare them for the reception of colors, either vegetable or mineral, but at the expense of durability. Black dyes are used more frequently than any other, and may be prepared by adding to a strong decoction of logwood a small quantity of the proto-sulphate of iron. For 50 pounds of hair, 25 pounds of logwood should be boiled in a suitable quantity of water for three hours, then the fire withdrawn, and 12 ounces of sulphate of iron introduced and stirred. The hair, washed in soft water to remove the lime, is then immersed in the bath and kept there for twelve hours or more.

The quality of hogs' bristles, in the natural state, varies with the age, sex, and habitat of the animal, and with the season of the year when slaughtered. Those from old are stronger than those from young swine, except that in extreme old age they lose much of their elasticity and are consequently less valuable. Bristles from the boar, whether wild or domesticated, are superior to those from the sow; and those from hogs slaughtered in winter are longer and stouter than those from hogs slaughtered in the summer. In summer they are curled and short, and it is only in winter that they attain their greatest strength and development. The best bristles come from swine habituated to the severe climates of the higher latitudes, where nature seems to have provided them with extra covering. Hence Polish, Russian, and especially Siberian bristles are long and strong; and it is from these countries that England and the United States draw a great portion of their stock to make brushes, for which the short and weak native products are not suitable. The longest and stiffest bristles grow along the spine of the hog, especially in the region of the shoulders, where they sometimes, in Siberia, attain the remarkable length of 12 inches. For several inches on either side of the spine, however, and sometimes well down on the sides of the animal, much of the hair is sufficiently coarse and stiff for many kinds of brushes. The whole hairy vesture of the hog is in fact turned to profitable account in one way or another, that which is too soft and fine for the brush-makers' use being sold to saddlers and upholsterers as "wool."

Bristles of excellent quality for many uses, though inferior in length and strength to those from Northern Russia, are obtained from France, Turkey, and Germany. In all these countries bristles have for many years formed a conspicuous article of commerce, especially in Germany, to which country's export has been added in the course of trade a considerable portion of those from Turkey and Russia.

The following is an extract from a book written by a German brushmaker of Dantzic:*

> Most bristles which come from the colder climates are black or gray, and need not therefore be dyed. Prussian bristles, which are generally gray, are not so long and thick as Polish and Russian. So-called German bristles are still weaker and shorter; but their intrinsic value, which is toughness, is greater than all others. Their color is almost white, termed "faded" in the terminology of the brush manufacturer. Since really no white bristles are to be found they must be bleached, which can only be done with difficulty. Only the bristles from the very top of the back of German swine can be used in brush manufacture, the others being too short and weak. In Germany, however, very many Polish and Russian bristles are consumed, besides those of native growth. In Berlin particularly there are several large factories which for the most part get their bristles from Dantzic, where merchants receive them from Polish Jews, who collect them all over Poland. These merchants export them either by the bushel or in bundles of five to ten pounds' weight to the brush manufacturers who have to assort them, as a bushel always contains several kinds. Although the exterior of the bristles may appear as if all the bristles were long and strong, yet those in the middle are frequently poor.
>
> In Germany the trade in bristles, like the fur trade, is mostly in the hands of the Jews. Russia has the largest export trade in bristles. England receives yearly

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* Neuer Schauplatz der Künste und Handwerke der Bürsten- und Pinselfabrikant. Weimar, 1842. Translated for this paper by C. Bjerregaard, Assistant Librarian Astor Library, New York City.

2,000,000 pounds from that country. The value of bristles imported into England in 1832 was 38,741 pounds sterling. The Russian export is mostly from St. Petersburg and Archangel. The best kinds are those called *Akatka* and the poorer *Suchoi*. Poland, too, has a large export trade in bristles, particularly to Posen, Krakau, Wien (Vienna), and Breslau. In Königsberg, whereto this article is brought principally by Jews, as also in Dantzic, they assort and divide the bristles into big bundles and little bundles. The first have little heads on the lower ends and the bristles are very stiff; the refuse is large; the bundle weighs from 6 to 7 pounds. This kind generally goes to England. The smaller bundles containing the shorter and softer bristles, weigh from one to two pounds and go to Holland.

In Königsberg it is also the practice to divide the bristles into crown bristles (*kronborsten*), crown refuse bristles (*kronbrackborsten*), and refuse bristles (*brakborsten*).

Nuremberg is, in Germany, the great market for bristles. There crude bristles are collected from all parts of Germany and assorted into box-bristles, parcel-bristles, and pencil-bristles. The last are gray, reddish-black, and faded in color, and are tied up in parcels each of a quarter of a pound weight. The assortment is regulated by the strength, length, and color; only the long ones are called box-bristles (*schachtelgut*). About three ounces are laid down in a box and sent to Italy and France, where they are used in the manufacture of the "wings" and the so-called "souls of shuttles". Raw bristles (*i. e.*, bristles not sorted), or raw hair, are those which the manufacturers buy by the bushel.

The Nuremberg bristle dealers have to first buy a permit from the corporation or guild before they can trade. Every trader in bristles must burn his stamp upon the box, and many stamps are considered a good thing. The best known are the Grapes, the Imperial Globe with a cross on it, the Oakleaf, the Fir Tree, the Lily, the Cup, the Post Boy's Horn, the Lamb, the Rose, the Image of the Virgin, the Arrow, the Anchor, &c.

Hungarian and Turkish bristles go by way of Triest, Vienna, and Prague to Leipsig, Breslau, and Nuremburg, where they are prepared for Hollandish and English use. All kinds of prepared bristles have their peculiar letters and numbers, and are also known by the countries whence they come. Hence the different and peculiar price lists. In Nuremburg bristles are also dyed in all desirable colors.

Besides Nuremburg, Hamburg has a great trade in bristles and exports largely to Spain, Portugal, North America, the West Indies, &c. In the trade is found a kind of "lime bristles" which, although they may be long and strong, are of poor quality, because they are obtained as a by-product from the tanning of hog skins. They make fair brushes and pencils, but do not wear well, as their strength has been impaired by contact with lime. They are readily recognized, for when they are bent short they remain in that position or break at once. Sometimes this inferior stock is mixed with good assortments, but to discover the fraud it is only necessary to test them, say fifteen or twenty at a time, to see whether or not they break.

The manufacturer of brushes must pay a much higher price for the dyed bristles than for the undyed, especially for those of scarlet. He ought, therefore, himself to dye them.

The dyeing of bristles is still a secret with certain manufacturers, who carry on their business with few workmen, and as the many have no knowledge of dyeing, we will here state what is necessary. For dyeing, the whitest bristles must be selected, unless they are to be dyed black, for which, of course, any other color can be used. They must be boiled for three hours in alum water with a little tartar, whatever color they are to have, even for black, because the boiling is necessary to make the bristles take the color. The bristles must not be put into the water in bundles, but must be untied. The fire must be kept up to give an even temperature all the time so that the alum water is kept boiling without interruption. There must not be little water and many bristles, because the water evaporates and the bristles become dry. The best preparation is: For one pound of bristles take three and one-half quarts of river or rain water, and dissolve into it half a pound of alum and two ounces of tartar. It is best to use a copper vessel for the boiling—one deeper than wide—because the water evaporates from it more slowly. It ought also to be kept covered, to prevent the too rapid escape of steam. Instead of a copper vessel one of clay may be used; yet the latter is less suitable because more easily broken. Whatever vessel is used, the boiling mass must be stirred up thoroughly every ten minutes. If the manufacturer can command a copper vessel large enough to contain 8 to 12 pounds of bristles at once in the alum bath, so much the more economical for him; yet he must take care to mix the alum and tartar in due proportions for the increased weight. During the last hour of boiling the dyes should be mixed and the color bath prepared.

Some idea of the importance of the bristle trade, as a feature of Russian commerce, is indicated by the following facts gathered from various authorities:

As early as 1793 the value of the bristles exported from Russia was reported to have been 742,000 rubles. For some years previous to March, 1845, when the duty was repealed, England's annual importations from Russia, France, and Germany amounted to about 1,800,000 pounds, all but 300,000 pounds of which came from Russia. After this time they soon exceeded 2,400,000 pounds, a like proportion, no doubt, still coming from Russia.

From a report on the animal substances displayed at the great exhibition in London in 1851 the following quotation is made:

> The finest specimens of bristles were sent by Russia, to which country that article forms a most important branch of trade, its export of bristles amounting to more than 2,000,000 pounds annually.

It is not likely, however, that the entire amount of England's importations of Russian bristles was consumed by English brush-makers, since, in later years, a portion of the Russian bristles imported by the United States has come through English ports, though *more* through German ports, as will be presently seen. The United States Census Report for 1870 furnishes the following statistics:

Number of brush-making establishments		157
Number of steam engines employed		18
Aggregate horse-power		257
Number of water-wheels employed		3
Aggregate horse-power		21
Number of hands employed		2,425
Number of males over 16 employed	1,481	
Number of females over 15 employed	522	
Number of youths employed	422	
Amount of capital invested		$1,683,993
Value of materials used annually		1,312,897
Amount of wages paid annually		691,405
Value of annual products		2,694,823

To supply this industry, which has increased rapidly during the last decade, not only a large amount of domestic stock has been consumed, but also considerable importations of foreign, as shown by the following figures from the reports of the Chief of the Bureau of Statistics:

Bristles received from Germany.

1872.	430,324 pounds	$592,794
1873.	559,818 pounds	721,537
1874.	464,487 pounds	568,766
1875.	442,283 pounds	567,786
1876.	551,302 pounds	531,503

Besides these importations from Germany, which are largely made up of Russian, Turkish, and Polish products, there were received during the same periods considerable quantities from England and France, but statistics are not readily obtainable.

The amount of the Russian product included in the aggregate of United States importations is difficult to determine. A duty of 15 cents a pound is collected at the United States custom-houses on all foreign bristles.

The Treasury reports exhibit the amounts received from various countries, together with the amount of revenue derived therefrom, but no statistics showing what proportion of the total importation was collected in Russia. The same may be said of Polish and Turkish bristles, these also finding their way through German markets to ports on the Baltic and North Seas, whence they are exported.

In former years, when all Russian stock was imported by sailing vessels direct from Cronstadt, the harbor of St. Petersburg, regular lists were published there showing the exact quantity of their exports to the

United States, such as bristles, red leather, hemp, &c., but as bristles are now imported in a roundabout way, that source of information is cut off. During the summer months Russian imports came by steamer from St. Petersburg to Lubeck, thence by rail to Hamburg, and from that port by steamer to New York; and during the close of navigation, from November to the middle of May, by rail from St. Petersburg to Hamburg and thence by steamer. New York receives the bulk of United States importations, the other Atlantic cities, as Baltimore, Philadelphia, and Boston, importing but a trifling amount, said to be not more than 10 or 20 casks a year.

St. Petersburg is the most important point in Russia whence bristles are brought. They are collected from amongst the peasantry all over Russia and Siberia by itinerant peddlers, and carried to the prominent centers of trade in the interior, where they are "dressed" and packed for shipment to St. Petersburg. The best come from Siberia, though formerly those from the Ukraine were most esteemed.

There are no abattoirs in Russia as in the United States. Most Russian bristles come from swine killed by peasants. The peasant wives usually assist in plucking the dead animals and are allowed the bristles. They assort them into colors and sizes, tie them in small bundles, and store them away to await the peddler's coming.

Frequently, in times past, the best of the bristles were reserved and allowed to accumulate until the occasion of a daughter's marriage, when they were given to her as a dower. Hence the name of "dower" bristles and the reputation they have had for excellence.

Russian bristles are assorted as to color into white, half white, yellow, gray, and black; as to length and stiffness into okatkas, firsts, suchoys, and seconds, in the order of excellence, okatkas being the best. There are also superior, extra, medium, and ordinary okatkas.

All Russian bristles are put up in bundles and tied with thongs of bark. Firsts, suchoys, and seconds in bundles of three to four pounds, and okatkas in bundles of about one pound. They are packed in the interior at Moscow, Jaroslav, Archangel, &c., in casks of about 1,000 pounds, and brought to St. Petersburg where they are unpacked, "bracked," and then repacked in smaller casks of about 500 pounds, termed by the Russians "boy-casks."

All bristles exported from Russia are inspected ("bracked") by four experts appointed for life, two Russians and two foreigners, who examine every bundle and throw out those which do not come up to the standard in length, strength, and color. These inspectors are called "brackers." That which is thrown out is termed "brack," and is sold at a lower price as inferior stock. Next to St. Petersburg the most important bristle market is Leipsic, where two or three fairs are held annually, the principal one being in the fall at Michaelmas time; bristles from Poland, Gallicia, and Turkey are found there, as well as some from Moscow. One or two of the principal packers have found it advisable to send their stock to Leipsic in preference to St. Petersburg, the expense being less and the bristles not being subject to "brack."

Königsberg is an important market for bristles, especially for Polish, Courland, and some Russian. The quality of Russian bristles is said to be by no means what it was a few years since. Crossing the breeds with Berkshire hogs, which yield excellent pork but have hardly any bristles, has softened the Russian stock.

The late Turkish war, while it did not sensibly affect the collection of raw material, is said to have somewhat reduced the product in quality, the hogs having been slaughtered when young and before the bristles had attained full development, in order to meet the demand of the army for subsistence supplies. On the other hand, it greatly influenced the money market, depreciating the currency and reducing the rate of exchange, thus greatly favoring the importer. The quantity collected has also somewhat decreased for the same reasons. It is ordinarily from 60,000 to 70,000 poods, a pood being equal to 36 American pounds, or about 4,000 casks a year, of which England takes the bulk. America comes next, and the remainder is divided between France and Germany.

The Russian crop:

	Poods.
In 1876	72,700
In 1877	78,000
In 1878	64,000
In 1879	53,000
In 1880	55,000

The 1880 crop of 55,000 poods was divided as follows:

	Poods.
Okatkas, stiff, 6 to 6½ inches long	6,400
Firsts, stiff, 4½ to 5 and 5½ inches long	12,800
Suchoys, soft, 5 to 5½ inches long	18,200
Seconds, soft, 3½ to 4½ inches long	17,600

Following is a general classification of the most prominent varieties of foreign bristles used by American brush-makers, giving lengths in inches and the prices per pound at New York quotations, corrected up to May 11, 1882. These prices will vary on account of variations in quality in the same brands, and with different dealers. Furthermore, bristles are, of course, subject to the same fluctuations in price as other imported goods, dependent upon the state of the money markets, the rate of exchange, supply, demand, &c. A considerable advance is noted in the past two years, especially in American, Russian, and French bristles, which are reported as growing scarcer and of poor quality. Brush-makers anticipate a further advance rather than a reduction in prices.

RUSSIAN BRISTLES.

	Per pound.
Okatkas:	
Superior:	
White, 6½, 6¾, and 7 inches	$2 50 to $3 50
Half white, 6½ to 7 inches	2 50 to 2 75
Yellow, 6½ to 7 inches	2 30 to 2 75
Gray, 6½ to 7 inches	2 30
Black, 6½ to 7 inches	2 40
Extra, same colors, 6½ inches	2 15 to 2 20
Medium, same colors, 6¼ inches	2 10 to 2 15
Ordinary, same colors, 6 inches	1 85 to 1 90, 1 95
Ordinary, same colors, 5½ inches	1 65 to 1 70, 1 75
Firsts:	
White, 4 to 5¾ inches	1 50 to 1 75
Yellow, 4 to 5¾ inches	1 50 to 1 75
Gray, 4 to 5¾ inches	1 35 to 1 50
Black, 4 to 5¾ inches	1 35 to 1 50

Many firsts have all the colors in concentric rings mixed in the same bundles and are sometimes called "plugged firsts." Such are, of course, sold at a lower price than those which have been dressed in separate colors.

	Per pound.
Suchoys:	
White, 4 to 5¾ inches, soft	$1 00 to $1 30
Yellow, 4 to 5¾ inches, soft	1 00 to 1 30
Gray, 4 to 5¾ inches, soft	90 to 1 20
Black, 4 to 5¾ inches, soft	90 to 1 20

Seconds:		
White, 3½ to 4½ inches	75 to	90
Yellow, 3½ to 4½ inches	65 to	70
Gray, 3½ to 4½ inches	55 to	65
Black, 3½ to 4½ inches	50 to	60

Seconds are shorter but not necessarily less stiff than suchoys. Anything above 4½ inches makes suchoys.

All Russian bristles are assorted into colors and grades as above, though there are many brands of varying excellence, taking their names from the packers or places where dressed.

Some of the brands best known in the American trade and highest esteemed are:

Brand.	Okatkas.	Firsts.	Suchoys.	Seconds.
	Inches.	*Inches.*	*Inches.*	*Inches.*
Kamtchatka	6½	5¾	5½	4¾
Bogomoloff	6½	5¾	5½	4¾
Grebenikoff	6½	5¾	5½	4¾
Suschkin	6¼	5 to 5½	5	4¼
Sossoff Zerschoff	6¼	5 to 5½	5	4¼
Mescatinoff	6¼	5 to 5½	5	4¼
Mestscheffsky	6	5	5	4

Russian bristles "bracked" at St. Petersburg, though shipped through German ports, generally remain in the original packages until they reach New York, and can be relied upon as of uniform and standard excellence as to length, strength, and color, according to brand.

About 10 per cent. of the contents of each cask are "extra long"; that is, they are from a quarter to a half inch above the specified length. The Government inspection is rigid and the inferior stock is always rejected. As noted in the preceding, however, certain Russian packers, to evade the "brack", take their stock to Germany and sell it at the fairs. Such Russian bristles are at least of uncertain quality, since there is no Government inspection of any kind outside of Russia.

GERMAN BRISTLES.

Tectiner bristles, dressed in Tectin, a small town in Russian Poland, are the most regular of those classed as German. They are really Polish, but are called German by dealers to distinguish them from other Russian brands. They are assorted into grades and colors as follows:

Extra Spitz Spitz:	Per pound.
White, 4¾ to 7 inches	$1 95
Yellow, 4¾ to 7 inches	1 60
Gray, 4¾ to 7 inches	1 40
Spitz Spitz:	
White, 4 to 4½ inches	1 45
Yellow, 4 to 4½ inches	1 35
Gray, 4 to 4½ inches	1 00

Spitz Spitz usually have the white and yellow mixed in the casks but not in the bundles.

Spitz:	Cents.
White, 3½ to 4 inches	90
Yellow, 3½ to 4 inches	85
Gray, 3½ to 4 inches	60

MEMEL.

These are tied in small bundles of 1 ounce to 1½ ounces, and are quoted as follows:

Extra Memel:	
White, 5 to 7 inches	$1 90
Yellow, 5 to 7 inches	1 50
Gray, 5 to 7 inches	1 35
Memel:	
White, 4½ inches	1 40
Yellow, 4½ inches	1 35
Gray, 4½ inches	1 15

In a cask of 600 pounds of Memel about 140 pounds are white, 200 pounds gray, and 260 pounds yellow. The colors are all mixed in the bundles.

German:	Per pound.
Firsts, white and gray, 4 to 5 inches	$1 50
Seconds, white and gray, 4 inches	75 to 90 cents.
Medium Pinsel } Paint and varnish stock	

German firsts and seconds are tied in "taper" bundles. About 15 per cent. are yellow, and the remainder white. There are many other brands and assortments of the lower German grades, but their names are of little value to the brush-maker, as both names and qualities are constantly changing.

Courland brands are similar to Memel in lengths, colors, quality, style of dressing, and price. Meseritzer brands are inferior to Memel, Courland, and Tectiner, and worth from 5 to 10 cents a pound less.

POLISH BRANDS.

Bristles from Poland, Eastern Germany, and the Ukraine are classed as Polish by most dealers, but are sometimes sold as Memel. They are tied up in bundles of a few ounces, and in colors like the Russian, white, yellow, gray, and black.

Polish:	Per pound.
White, 4½ inches	$1 45
Yellow, 4½ inches	1 45
Gray, 4½ inches	1 25
Black, 4½ inches	1 25

	Per pound.
Polish white and yellow, 4¾ to 7 inches	$1 95 and upwards.
Gray and black, 4¾ to 7 inches	1 65 and upwards.

KÖNIGSBERG BRANDS.

	Per pound.
Prussian, shoe, soft white, 5½ to 7 inches	$1 65 to $1 85
Inch, stiff, white	2 00
Inch, stiff, yellow	2 00
Crown, white, 4½ inches	1 15
Crown, white, 4 inches	85

TURKISH BRANDS.

Gallician and Austrian bristles are sometimes found dressed as Turkish, though Gallician are often sold as such, and Austrian as Memel.

The colors are white, gray, and black; and each color is tied up separately in bundles of 2 or 3 ounces. The small bundles are then bound together into larger bundles of 1 or 2 pounds, each composed of various colors. The stiffest Turkish stock comes from Bucharest; Leipsic is the principal market, and Hamburg, Stettin, and Lubeck the points of exportation.

	Per pound.
Turkish, 4⅓ to 7 inches, white	$2 00 to $2 25
Turkish, 4⅓ to 7 inches, black and gray	1 65 to 1 80

FRENCH BRANDS.

French bristles are mostly white; they are bleached nicely, dressed, packed in small bundles, and preserved from moths by paper wrappings. They are usually imported in 50-kilogramme cases, with assorted lengths in each case. The most important brands are dressed and packed in Paris. The most prominent dealers are Deseglise Freres and A. Dupont. Some of the principal brands are:

Deseglise, 1-7 [Nos. 1 to 7], préparée	$1 40
Deseglise, 2-8, beau blanc	1 85
A. Dupont, 1-7, demi blanche	1 10
A. Dupont, 1-7, préparée	1 20
A. Dupont, 2-8, beau blanc	1 65

There are extra sizes (4-7 and 6-12) that are only imported against special orders and the prices are not quoted. There are also qualities selected out of the beau blanc called:

Beau blanc forte, 2-10	$2 50 to $3 00
Beau blanc "extra" forte, 2-10	3 25 to 3 50
Beau blanc "extra" forte, zero	4 50 to 5 00

Lately a great many special sizes have been sold; that is, selected bristles for special purposes, for which special prices have been paid.

French bristles are of a peculiar pearly whiteness, and are assorted and dressed with great care. The "flags" are washed clean without having been broken or worn away in the process, and are, therefore, soft and white, and especially suitable for artists' and painters' tools. The finest tooth brushes are also made of French stock.

The lengths of French bristles are designated by numbers, though the same standard has not been adopted by the different packers. Deseglise No. 1 is 2¾ inches and A. Dupont No. 1 is 2½ inches long. The numbers run from 1 to 12 and occasionally higher. The difference between any two consecutive numbers is one-quarter of an inch.

AMERICAN BRISTLES.

SOURCE.

Dressers and packers of American bristles obtain the "raw hair" from the great pork-packing establishments in the Western States, some from the smaller abattoirs in the East, and, no doubt, a comparatively trifling amount from small collectors who receive them from peddlers, as in Russia. Contracts for bristles and hog's hair, at a stipulated price per hog, are made by the bristle merchants with pork-packers at the beginning of the winter packing, for the season commencing November 1 and ending March 1, and for the summer season, commencing March 1 and ending November 1. The contractors generally employ their own pullers, who, as fast as the dead animals are scalded, pull out the longest of the bristles along the back and put them into barrels, taking care to separate the colors. The remainder of the bristles and soft hair is then scraped off and thrown on the floor where each day's product remains until the following morning, when it is gathered up and carted away to a field, rented or purchased for the purpose, and spread on the ground. There it remains until it has become thoroughly cleansed and "cured" by the frost, snow, and rain. In May or June, or later, according to season, it is raked up, pressed into bales, and taken to the dressing factory or to the market. This poorer quality of field-bleached bristles is said to form a considerable article of export. The better quality is shipped in the barrels to the dressing factory whenever a car-load has accumulated.

DRESSING.

The process of "dressing" or preparing "raw hair" for the hand of the brush-maker involves the following operations, viz, "soaking," "wet-combing," "washing," "bleaching" (white stock), "straightening," "drying," "separating," "dry-combing," "dragging," and "bundling." The bristles which fall to the floor during these operations are termed "riflings"; they are restored to a condition suitable for brushes by "picking," "recombing," "turning," and "dragging" as before. What finally remains is called "wool," and is sold to saddlers and upholsterers for stuffings, or "curled" and used for mattresses, &c.

SOAKING.

When bristles are received at the factory they are immersed in fresh water while still in the casks, holes having first been bored in the heads to admit the water. The object is to stop any fermentation that may have begun, and to soften the dermatic and other impurities that adhere to them so that they can be easily combed and washed. The bristles are pulled off in large tufts or flakes and thrown into the casks with the roots adhering, and they are soaked in the casks to avoid the disarrangement that would result if removed and soaked in open vats.

WET-COMBING.

After several days' soaking the bristles are removed from the casks, the workmen picking out the flakes as they were removed from the animal, and piling them on benches with the flags all in one direction. They are then, while still wet, gathered up in convenient maniples and combed on a steel-toothed comb attached to the front of the bench, roots and flags alternately, to separate them and remove as much of the adherent matter as possible. The bundles are then stacked up in tubs in concentric rings, with the flags toward the center.

WASHING.

These tubs when full are removed to the washing room, where rows of small vats, raised to the height of an ordinary work-bench, are arranged in pairs with a faucet over each, one for the supply of hot water and the other for cold water.

The bundles of bristles are removed from the tubs one at a time and washed, first in hot and then in cold water the workman holding the bundle in his hand and manipulating it so as to thoroughly wash it and at the same time to prevent the disarrangement of the flags and roots.

In washing white bristles intended for paint and varnish stock strong soap is used, and the flag ends of the bundles are rubbed on the flat surface of a sharp-grained stone, such as a grindstone. Care must be taken, however, not to scour off the flags; otherwise they would be ruined for the purpose intended. After washing, the bristles are repacked in clean tubs in the same arrangement as before, the black going to be straightened and the white to be bleached.

BLEACHING (WHITE STOCK).

The bleachery is usually a small brick or wooden building, divided into compartments of convenient size, each having below a pit about 2 feet deep, in which sulphur is burned, and above, wooden gratings in tiers, on which the bristles are spread. After being exposed to the fumes of the burning sulphur about twelve hours they are returned to the factory, and subsequently treated precisely like the colored stock.

STRAIGHTENING.

All bristles, especially those collected in summer, are naturally curved or bent, and must be straightened before they are fit for brushes. To effect this boys are employed to bind them together in bundles of 2 or 3 ounces, usually with a stick in the middle. After binding the bundles are arranged on wooden racks inside a steam-chest, and live steam turned on for several hours.

DRYING.

On removal from the steam-chest the bundles are carried to the drying-room and spread on gratings similar to those in the bleachery. Coils of steam pipe, usually on the floor, supply the necessary heat.

SEPARATING.

After being thoroughly dried they are unbound from the sticks and arranged in boxes, still keeping the roots and flags together. At this stage they are somewhat matted together, and to separate them before combing they are passed through a machine expressly designed for the purpose. One consists of two fluted pieces of cast-iron the corrugations fitting into each other like the teeth of gears. The lower one is stationary and the other made by appropriate machinery to rise and fall upon it with a kind of sliding motion. An endless belt runs between them in a direction at right angles to the grooves, upon which the bristles are spread transversely or parallel to the grooves. A cut of this machine is not readily obtainable. Another machine for this purpose, patented by W. F. Parks, is represented in Plate I. This machine consists of a contrivance by which the adhering masses of bristles are made to pass between two surfaces, the lower one of which is a moving band or belt, on which the bundles of bristles are spread, and which carries them underneath an inclined slide which is separated from the belt at the end where the bristles are inserted far enough to permit their easy introduction, and approaches so near to it at the other end as only to permit the separated bristles to pass out between it and the moving belt. A reciprocating motion is given to the slide so that while the bristles are being carried forward on the belt they are at the same time being rubbed by the slide, thus cleaning and separating them before their exit at the narrow opening. Fig. 1 represents a longitudinal section of the machine through the line A B. Fig. 2 represents a plan and Fig. 3 a cross-section through the line C D of the plan. M represents the endless belt carried upon rollers whose journals are shown at *a a.* N represents the slide to which the guides *o o* are attached, moving to and fro upon the bars *b b*, which are attached to the frame. P is a lever, pivoted at R, which, together with the crank T and the connecting-rod S, imparts reciprocating motion to the slide N. The distance between the slide and belt is about one-sixteenth of an inch at one end and about five-eighths of an inch at the other. The slide has a reciprocating motion of about 3 inches. Both slide and belt are provided with transverse ridges to insure a more thorough rubbing of the bristles. The stock is gathered up as it leaves the separating machine, carefully replaced in the boxes, and carried to the combing machines.

COMBING.

There are several varieties of these machines, some of them combining the operations of assorting (sometimes termed "back-dragging"), combing, turning, and dragging. It is doubtful, though, whether these more pretentious mechanisms are entirely satisfactory, since in some of the largest factories machines are preferred which do the combing only, the dragging, assorting, and turning being effected either by hand or by separate machines. In the largest brush-making establishments, even where raw hair is used, these operations, with the exception of turning, are performed by hand.

A combing-machine, such as that last referred to, is represented in Plate II. It was invented by N. H. Spafford. It may be described as consisting of a horizontal rectangular iron-bed, about 4 feet long by 1 foot wide, supported on four legs and surmounted in the center by a square, tower-like frame, *a a*, Fig. 2, whose sides meet at the top like the rafters of a house. Revolving in this frame, with its axis about a foot above the bed, and parallel with its sides, is a shaft, *b*, with both ends projecting a few inches beyond the journal-boxes. On each end of the projecting shaft is a crank which carries a pitman sliding through an oscillating-guide, *d*, attached to the frame. Attached to the lower end of each is a comb, *c*, with eight or ten steel teeth about 3 inches long. Power is applied to the shaft *y*, and rapid motion is communicated to the cranks by means of the belt X. At each end of the horizontal frame is a drum, A and M, Figs. 1 and 2, each with four grooves, around which run four belts or cords. Beginning with M, two long belts or cords pass under the pulley K, over the pulley I, under the two central pulleys, then over the drum A. Beginning at the same point, the two remaining cords pass under the two central pulleys over the pulley G, under the pulley E, and finally over the drum A. Two cords or belts also pass around pulleys K and T, whose axes are so situated that the lower branches of these cords bear upon the surface of the pulley I, one between the two right-hand cords passing over M and A, and the other outside to the left. Similar cords pass over E and S bearing upon G. Motion is imparted to this system of pulleys and drums by means of a worm gear and toothed-wheels, shown in Figs. 2 and 3. A flat belt 2 inches wide passes around the pulleys N and Q, which are driven by beveled gears shown in Fig. 3. This last belt serves as a guide against which the butts of the bristles are placed when feeding them to the machine. To operate the machine the bristles to be combed are placed on the long, round belts above the plate O, with their butts resting against the small flat belt P, which latter moves along as the round belts are moved, and guides them until they pass under the pulley K. When the bristles have passed pulley K they rest upon pulley I, and their butts are held firmly between the two sets of round belts just described, while the flag-ends, which are free, are exposed to the action of the comb C; thence they pass on under the pulleys S and T, and while their flags rest on pulley G, and are held as before between the two sets of round belts, their butts are combed by the comb *f;* finally they are received by the operator as they pass over the drum A, and are carefully piled in boxes ready for the next operation. The weights attached to the elbow-levers D and L, combined with the set-screws and slots in the boxes B B, give the required tension to the belts on the pulleys which they connect, and permit the passage of larger or smaller quantities of bristles along the belts, holding them with nearly the same firmness while being combed. A counter-weight *i* on the crank-shaft balances the combs. Sometimes it is found necessary to pass the bristles through this machine several times before all the dirt, doubled hairs, and "wool" have been whipped out and they are sufficiently clean to be "dragged" and "bundled."

Another machine for combing bristles, patented by W. F. Parks and L. F. Lannoy, is represented in Plate III. This machine operates on a different principle, and its service requires much more care and labor from the operator than the preceding. Bristles to be combed by this machine are secured in bundles of suitable size in a kind of clamp represented in Fig. 3; the butt ends are compressed between the padded jaws S S′, Fig. 5, by a partial revolution of the eccentric R. To operate the machine, the loaded clamp is inserted in the dovetail slot *c* (at a point where the dovetailing is cut away to receive it), with its tongue in mesh with the screw D, and with the flags of the bristles presented to the action of the comb. The rotation of the screw D gives the clamp a motion of translation, while the dovetail Q, engaging under the flange *c′*, holds the clamp down to its bearings. As the clamp advances the comb begins to engage, by means of its shortest blade, in the bristles, and, as the clamp is drawn forward, the succeeding blades engage until all are in operation on different parts of the bunch, each succeeding longer blade rehackling with deeper penetration the portion already traversed by its shorter predecessor and more completely ridding the bundle of "shorts" and "doubles." On reaching the next opening of the slot C the clamp is withdrawn and temporarily unclamped, and having had the butts of the bristles sufficiently protruded for combing, is reclamped and inserted end for end in the slot, upon which the work proceeds as before. As many bunches may be simultaneously undergoing treatment as there are combs in the machine.

DRAGGING.

Dragging is the name given to the process by which bristles are assorted into different lengths or sizes. The bristles having been thoroughly washed, bleached, and straightened, and having had all the dirt, "shorts," and "doubles" combed out, are taken, a few ounces at a time, struck on the bench to even the roots, then set flags uppermost in a wooden frame with a movable side, in very much the same manner as type is set in a printer's composing-stick. The frame is about 18 inches long and 2 inches high. Against the *fixed* side is placed a strip of tin 2¼ inches high, and extending the whole length of the frame. Inside this are placed other similar strips of tin, each succeeding strip being a quarter of an inch higher, until the last, which is a quarter of an inch *lower* than the height of the longest bristles to be "dragged." When a sufficient quantity of bristles has been placed in the frame, the adjustable side is pressed against them by a cam and lever, clamping them close against the tin gauges. The workman then proceeds to "drag" out all the bristles that project above the highest strip of tin, seizing them by the flags between the thumb and the edge of a dull knife. These are all laid in a tier by themselves, the first strip of tin removed, the compress tightened, and the next size, a quarter of an inch shorter, "dragged" and piled also by itself.

American bristles are usually dragged down to 2¼ inches. The residue after the final dragging is denominated "bottoms." The assorted sizes are termed "draggings."

In brush factories using "raw-hair," and in small dressing establishments, the dragging is done without the aid of machinery of any kind. The workman holds a small bundle loosely in his left hand and drags out the longest bristles by the flags as before, frequently "butting down" the bundle to keep the roots even, and applying it to a "size stick" (an instrument to be presently described) to determine the lengths. Power machines, more or less automatic, are sometimes applied to this operation, but they are complex and expensive, and only used in some of the largest factories. Such a machine, patented by N. H. Spafford, is represented in Plate IV. The operation of this machine, briefly described, is as follows: The bristles are placed in the box H, flags uppermost, carefully "butted down," and further secured by the spears or skewers *a′ a′ a′*, passed through them near the butts. The box is then secured to the carriage O, and power is applied at the point indicated by the crank M. The machine being in motion, the box of bristles is fed forward by means of the cam-slot D, the lever S, the wheel R, the pinion P, and the rack Q. The crank 11 and pitman N (Fig. 8) give a reciprocating vertical motion to the slide G, which carries a pair of nippers, G G (Figs. 1, 3, and 4), made to open and close at the proper times by means of the arm K (attached to the axis of the movable jaw) and the cam stops 21 and L. *Descending*, the open nippers enter among the flags of the bristles in the box H, and are closed by the arm K striking the cam-stop L. *Rising*, the nippers carry with them the long bristles that have been nipped by the flags, until, when near the upper limit of their motion, they discharge their load by the action of the arm K and the cam-stop *e′*. At the moment of their release from the nippers, the bristles are caught by the arms *n n* of the bent lever U and pressed against the slide-bar F over the mouth of the receiving-box I, where they are held until the slide F has been withdrawn by means of the lever E and the cam-slot in the large cylinder; when the arms again move forward, putting the bristles into the box beyond the range of the slide-bar F, which is forced back across the mouth of the box in rear of the bristles, holding them in place, while the arms sweep back over the nippers, ready to repeat the operation. In order that the bristles in the receiving-box shall always be kept firmly in place, as the slide I′ is forced back by every successive addition of bristles, the slide has a spring clamp mounted on its guide-rod 3 (Fig. 2), on the inside of the box and bearing against its end, by the friction of which on the rod, as the latter is forced through it by the compression of the bristles, the rod is prevented from passing through farther than is actually required for each additional lot of bristles.

BUNDLING.

The "draggings" finally pass to the bundler, who takes a sufficient quantity (about a pound of "bottoms," or more of larger sizes) to fill a tin band of a certain diameter, and squeezes them into a cylindrical bundle by means of a hand press, so that the band can be passed over them. The "flags" are usually wrapped in paper, over which the ring is slipped, and finally pushed down to the root end of the bundle after removal from the press. Sometimes a ligature of stout twine is substituted for the tin band. The sizes and qualities are marked on the wrappers, and the bundles are packed in barrels for the market. This bundling press is of the simplest construction, being merely a block of wood whose thickness is considerably less than the length of the shortest bristles, lying flat on the bench, and having a hole through it, in shape like a right cylinder with a vertical axis. One-half of the concave surface of the cylindrical opening is formed on a second block, fitted into the first, and having a sliding motion like the dies in a die-stock, and operated by a screw in the same manner, or by a lever, which may be substituted for the screw. In some of the larger bristle factories more complicated devices are employed to facilitate the operation of bundling. One of the simplest of these is represented in Plate V. It was patented by L. F. Launoy. A bundle of bristles being inserted butt downward in the oblong space formed by the two guides E E′ and the indented jaws B C, a depression of the treadle F operates to close the jaws and to compress the bundle into a cylindrical form. The movable jaw C being held at one end by the pivot D, and at the other by the concentric guides E E′, is not liable to jam or bind in its operation, nor to be otherwise deranged. The location of the indentations being at the end of the jaws remote from the pivot, gives the requisite capacity, and permits the operator to be close to his work. The fixture of one jaw to the bench, and the treadle and spring attachment to the other jaw, enables the device to be worked by the foot of the operator, leaving his hands at liberty. The table A serves as a support to the machine as well as a gauge for the bristles.

RIFLINGS.

The term "riflings" is applied to the bristles which fall to the floor during the various operations and manipulations of dressing, as well as to the sweepings from the floors of the brush factory. White stock is always handled by itself, so that white riflings rarely become mixed with those of other colors. All other riflings are mixed indiscriminately. They are swept up from the floor, and either fed by handfuls to the combing machine again and again, until the whole mass, with the exception of the fine hair or "wool," has been arranged in bundles, with hairs all parallel, but of different lengths, and with "roots" and "flags" all mingled together, or they are taken to the picker-room, and when a quantity has accumulated are put through the picker to clean and mix them as a preliminary to the combing. Some riflings are sold for cheap brushes (mostly prison-work) in the condition they are left by the combing machine, except that they are bundled together. White riflings, and most others long enough for paint brushes, are "turned" and "dragged" to sizes before being sold.

PICKER.

The picker is a machine consisting of a hollow cylinder with spikes projecting radially from the surface, and with a horizontal shaft through the axis about which it revolves, and an enveloping cylinder a little larger than is necessary to permit the rotation of the spiked cylinder. The ends and upper surface of the exterior cylinder are solid, the lower side being composed of iron rods 2 or 3 inches apart and parallel to the axis. When the machine is in motion the riflings are fed to it by a slightly inclined chute and through an opening in the side about the height of the axis. The dirt falls between the iron rods, and the bristles are blown out at the rear, thoroughly mixed by the rapid motion of the spiked cylinder.

In factories not provided with combing machinery, riflings, on coming from the picker, are taken by the combers, piled on benches, sprinkled with water, and then kneaded by hand into rolls of two or three pounds. The operator, holding a roll near the end, combs a few inches of that end on a comb attached to his bench. The short hair and "doubles," being combed out, fall to the floor as "wool," and leave the bristles at the end of the roll projecting in parallel points. The operator, seizing these points between his thumb and forefinger, drags them out and piles them on his bench. This operation is repeated until the whole roll has been combed and dragged. This stock is tied up in bundles of about a pound and laid aside to dry; the object of the tying is to keep them straight while drying. This process (sometimes termed "back-dragging") leaves riflings in the same condition when dry as the combing machine—of all lengths and with flags and roots all mingled together.

TURNING.

In order to "turn" the combed "riflings" so that all the "flags" shall be collected at one end of the bundles and all the roots at the other, advantage is taken of the peculiar structure of the bristle to effect the object by means of machinery.

As explained in the foregoing, all bristles are covered with minute scales or barbs, pointing toward the "flag" ends; so that if a number be laid side by side on a piece of fine sand-paper, with the roots half one way and half the other, and a piece of hard India rubber be pressed upon them and given a slight motion back and forth in the direction of their length they will be gradually pushed out roots foremost in opposite directions until they are separated into two rows, with the "flags" of one turned toward the "flags" of the other. The machine by which this "turning" is effected consists of a table with a strip of fine sand-paper about 5 inches wide, pasted along the middle for about 4 feet from right to left in front of the operator. On the sand-paper the bristles are spread, lying transversely, and along the middle of the row of bristles is laid a strip of India rubber, let into a groove in the lower edge of a board 4 or 5 inches wide. Motion is given to the board by means of a shaft at the rear of the table (a little shorter than the board), and connected with the latter by a connecting-rod and eccentric at each end. The eccentrics are set at the same angle and have but little—probably about two-tenths of an inch—eccentricity. The connecting-rods are secured to the board so as to hold it firmly in a vertical position when its rubber edge is pressed on the bristles. The machine is usually started and stopped by means of a "shipper" operated by the foot.

Plate VI represents a "turning" or "separating" machine such as has been described, with the addition of two pairs of cylinders, M M and L L, between which the bristles pass as they are pushed out butt end foremost by the rubber J. The rollers are not an essential part of the machine; the rubber without them does very good work. The machine in Plate VI was patented by A. Randel.

Plate VII represents a more complex machine for the same purpose patented by N. H. Spafford. The operation of this is essentially the same as the preceding, both being designed to separate bristles having their "flags" in *one* direction from those having their "flags" in the opposite direction by rubbing them in the direction of their length between two suitable rubbing surfaces. The improvement seems to be the arrangement by which the bristles are fed continuously to the machine at one end, while they are received at the other ready for use. Referring to Plate VII, Figs. 1 and 4, the crank on the shaft E indicates the point where the power is applied. Rotary motion is imparted to the shafts P and T by means of worm gearing shown in Fig. 4. The large pulley R, which carries the traveling platform W, is driven by the belt from pulley Q. The flat leather belts *y y y* rest upon the traveling platform and pass around the cylinders *a a*, which are revolved by crossed belts from pulleys C C to pulleys B B. The rubbing device, which corresponds to the board with its India rubber edge in the machine just described, consists of a round band stretched over the grooved pulleys S S, the lower branch of which passes through a groove in the under side of the frame V and is pressed down in close contact with the central leather belt *y*, which is in turn supported on the traveling platform, as above described. The central portions of the shafts P and T are squared, so as to insure rotation of the grooved pulleys S S, and at the same time to permit free motion to the latter in the direction of their axes. The frame V is attached to the pulleys S S in such a manner as to carry them with it in its sliding motion without interfering with their rotation. Jointed to the side of the frame V are two connecting-rods, J J, fitted to adjustable eccentrics *h h* on the small shaft G. A belt around pulleys F and L drives this shaft, which, by means of the eccentrics and connecting-rods, gives a reciprocating motion to the sliding frame V and produces a rubbing of the round belt upon the flat belt under it. All the motions described are communicated to the different parts of the machine by the revolution of the shaft E. Bristles to be "turned" or "separated" are spread evenly across the middle of the three belts *y y y* while the machine is in motion, and are carried under the round belt on the pulleys S S. The round belt, with its oscillating motion, operates on the "beard" of the bristles exactly the same as the rubbing board of the machine previously described. The important difference between the two machines consists in the adaptation of the latter to continuous operation, thereby saving the time that would otherwise be lost in stopping to introduce or remove the bristles in separate lots.

Plates VIII and IX represent an ingenious device for effecting the same object by means of another peculiarity of the bristle, viz, the fact that the center of gravity is not coincident with the center of figure, but is nearer the root end, so that a bristle, when dropped in a still atmosphere, will fall butt end downwards. The splayed flag, operating like the feathers on an arrow, also assists to produce the same result.

The apparatus represented in the plates referred to was devised and patented by Alfred S. Miles, of Brooklyn, N. Y., in 1881, and it is not known whether it is yet in practical operation. Fig. 1, Plate VIII, is a perspective view, showing the arrangement of the principal parts, viz, the funnel S (down which the bristles are dropped), the chute T, and the receiving-tray A. The chute T does not entirely intercept the fall of the bristles, being only sufficiently inclined to direct them into the revolving tray at its mouth. The converging ribs or ridges on the bottom of the chute are designed to prevent the bristles from turning as they descend, and to insure their discharge butt end foremost into the receiving tray. A motion of rotation about its vertical axis is given the tray, in order that the bristles shall be evenly distributed and lie parallel to each other, with their flags toward the chute. Figs. 2, 3, 4, and 5, Plate IX, are different views of the parts shown in Fig. 1, with some details added which will be readily understood.

After turning by either of the methods described, the bristles will be found to lie with their flags *nearly* all in the same direction. A few, however, always escape the "turning," and recourse is had to a very simple but ingenious process for drawing out those whose "roots" still remain among the "flags." The workman, holding them in bundles firmly by the root ends, draws the "flags" over a very fine sieve until all the unturned bristles have been caught by their root bulbs in the meshes and pulled out. These are finally withdrawn from the sieve by hand, reversed, and returned to the bundle. Turned riflings are sometimes "dragged" to sizes by the process already described, and sometimes sold as "taper" stock, to mix with "dragging" for the lower grades of painters' tools, &c. Some of the more extensive brush manufacturers buy their stock in the "raw" state and dress it themselves, doing much of the work, however, especially the combing, by hand, even when power is available and used for other purposes. They get their supplies from small collectors, who do little more than partially assort them into colors. The operations of dressing are essentially the same whether by hand or by machinery.

MIXING.

Gray stock is a mixture of bristles of various colors. When such bristles are cleaned and prepared for the market they must be thoroughly mixed, so as not only to present an uniform gray color, but be free from what are called "holes," caused by clusters of short bristles being surrounded by longer ones. When the mixing is done by hand the bristles are spread in a row on the bench, and the arrangement of the colors and lengths is determined by the eye. When the distribution seems fairly even, they are gathered into a bundle and alternately combed and "cut" (a process analogous to the cutting of cards) until all the parts of the bundle have been transposed and intermingled. Then they are spread on the bench, as before, and the hand-mixing is continued. These operations are repeated until the required uniformity of color and average of length are obtained. This operation is tedious and requires skillful manipulation to produce satisfactory results. Mixing is generally more thoroughly and economically done by machinery. For mixing short stock before "turning," the ordinary picker heretofore described serves a good purpose, but for the better qualities of dressed bristles a more complex and effective mechanism is used. Plate X represents a "mixer," patented by Theodore Dost, and designed to accomplish the mixing and remixing above described by passing the bristles under a succession of wire-toothed cylinders, doffing-rakes, and fan-rollers. Fig. 1 is a plan of the machine, showing the driving-gear. Fig. 2 is a section through *x x*, showing the working parts without the driving-gear. Fig. 3 is a plan of a cylinder and doffer, on a larger scale, showing the parallel rows of wire prongs, with the teeth of the doffer operating in the intervals. Fig. 4 is an enlarged section through cylinder, doffer, and roller. A A is an endless brush-belt, whose tufts have the stiffness of a common horse-brush. The belt moves in the direction of the arrows over the pulleys E E. B B B are cylinders about 6 inches in diameter and 3 to 5 inches long, armed with radial wire prongs set in rows corresponding to the intervals between the teeth of the doffer. C C C are the stationary doffers or rakes, whose teeth lie between the rows of wire prongs on the cylinders, and gather any bristles which the prongs bring up from the brush-belt, letting them fall on the fan-rollers D D, which revolve in the direction of the arrows and return the bristles to the brush-belt, which carries them to the next cylinder, where the operation is repeated. To operate the machine, the bristles are spread across the brush-belt at the end *a*, and are carried under the cylinders, each of which in turn rolls them over and over, mixing them, as explained, both as to color and length. After passing the last roller the bristles are gathered up for bundling or such further treatment as may be desired. The pronged cylinders make from eight to twelve revolutions per minute, and the fan-rollers from 300 to 500 per minute.

COLORS.

The colors of American bristles are white (bleached), gray, and some black. They are principally obtained from the Berkshire breed of hogs, and are mostly gray. There are few white American bristles in the market, and these are constantly growing scarcer.

LENGTHS.

American bristles are soft and mostly short; in fact, shorter and poorer as the breeds of hogs are improved. At some establishments where American bristles are dressed the French method of designating sizes has been adopted; generally, however, lengths are specified in inches by actual measurement. Mr. William Wilkins, of New York, who has a factory in Baltimore, has adopted the French style; Messrs. Lewisohn Bros., whose factory is at Pawtucket, R. I., specify the real lengths of their stock in inches as follows, viz, 2¼ inches, 2½ inches, 2¾ inches, 3 inches, 3¼ inches, 3½ inches, 3¾ inches, 4 inches.

CASINGS.

In dressing bristles it is the custom to select some of the stiffest and to call them "casings," but the percentage of such stiff stock in the ordinary American product is very small, and, as said before, is becoming smaller every year. "Casings" are so called from their use as mere envelopes to cover inferior centers, both of finished paint brushes and bundles of dressed bristles, foreign and domestic.

PART II.—VEGETABLE FIBERS.

TAMPICO.

Next to bristles in importance as a brush material comes a vegetable fiber known to the brush-maker as "Tampico" or "Mexican grass," and to the trade as "istle."

The name "Tampico" has no significance, being merely the name of the Mexican port whence much is imported. The term "grass" is a misnomer, as it has none of the distinguishing characteristics of the grasses. Istle is a fiber extracted from the thick, fleshy leaves of a wild tropical plant of the pine-apple family. It is imbedded in the soft, pulpy portion, from which it is separated by scraping and washing.

Although istle and tampico are to the brush-maker synonymous terms, only the coarsest of the istle is tampico, while much that goes under the latter name is doubtless the product of a kindred family of plants—the agaves. Tampico may be described as consisting of very coarse—nearly white—filaments of extraordinary strength and flexibility, smooth straight, and from 1 to 3 feet long. The fibers are thick at the base o, the leaf and taper toward the tip, and for half the length or more are as stiff as bristles. It readily receives and holds color, either vegetable or mineral, without injury, and may be dyed to resemble bristles so closely that when mixed with them in small proportions and made into brushes it is not readily distinguishable, except by experts. It is, however, less elastic than bristles, and if a brush composed of it be trodden upon, or otherwise violently compressed in the direction of the length of the fiber, it will not return to its original position so readily as bristles. When ignited it is consumed rapidly with a bright flame, like flax, and without the peculiar odor of burning hair. By one of these tests its presence among bristles can generally be detected. It is cut into lengths and used, either alone or mixed with bristles, in the manufacture of many kinds of brushes, particularly floor, bench, and molder's brushes. Sometimes it is used in the manufacture of cheap paint-brushes, but such are of inferior quality, in fact, unfit for anything but the very coarsest kind of painting. Scrubbing-brushes are usually made of pure tampico, but being used wet and frequently in hot water, they have little durability, and, indeed, little to recommend them but their cheapness. For brushes to be used dry, however, such as floor-brushes, dusting-brushes, clothes-brushes, and brushes for polishing leather work, tampico serves a useful purpose, though still inferior to bristles. When imported it is tied in bundles of about two pounds, with the thick ends together (Plate XI). It is imperfectly cleaned and contains much tangled fiber. To prepare it for the hand of the brush-maker it is hackled, combed, dyed, cut to lengths, and mixed as to colors, and with other stock. In some of the larger brush factories, having facilities for these operations, this material is obtained in the raw state and dressed by hand. A majority of brush-makers, however, obtain it ready for use, from factories where its preparation is made a specialty.

The process of machine dressing is explained in the following extract from a "Circular to brush-makers," issued by the Tampico Dressing Company of Burlington, Vt.:

> * * * For the ordinary product the stock, after being hackled, is cut to an uniform length for dressing and mixing, say 6 or 8 inches long, and after being spread in layers, butts and flags intermingled, it passes one end at a time before a swiftly revolving comb, which being repeated several times, whips out the loose ends, dirt, and wooly fiber, until a cleaner and more evenly-mixed product is turned out than can be furnished by hand labor. After being bunched up and secured in quantities convenient for handling, the ends are trimmed and it is cut accurately to the lengths required, and is ready to go into the brush without waste, shrinkage, or trouble. * * *

This machine product is claimed to be cheaper than hand-dressed stock. The inevitable loss from waste and shrinkage by the latter process is said to frequently amount to 25 per cent. Besides being dyed, tampico is made to still further resemble bristles by being put up in taper bundles, with the taper ends softened in imitation of the flags. Figs. 1, 2, 3, 4, Plate XII, are representations of specimens of this tapering stock furnished by the Burlington Tampico Dressing Company. These are mixtures of tampico and horse hair, tampico and bristles, and tampico, horse-hair, and bristles. The mixtures vary in the proportions of hair and fiber, in color, degree of stiffness, and style of dressing. The method of softening the flags or taper ends is not known. Figs. 5, 6, 7, 8, 9, represent specimens cut into lengths ready for drawing; 5, 6, 7, 8, solid tampico; and 9, a mixture of tampico and piassava. Fig. 5 represents gray stock (a mixture of black and white fibers). Fig. 6, black;

Fig. 7, white; and Fig. 8, reddish gray. The combing machine referred to, and upon which these samples were dressed, operates in much the same way as that shown in Plate II. It is described in letters patent No. 184,940, issued to E. B. Whiting, November 28, 1876. It has lately been proposed to make use of this fiber in the fabrication of nose bags, lariats, and saddle-girths for cavalry and artillery. The experiment has not been fully tried, and it is not known which of the many leaf fibers of the tropics is the best adapted for such uses. In view, therefore, of the little that is known of them, of their growing importance in the arts, and of their possible usefulness for so many military purposes, it is thought a more comprehensive presentation of the subject than is strictly germane to brush-making would not be entirely out of place and without value here.

TEXTILE FIBERS.

Following are extracts, "*passim*," from a work by the Hon. E. G. Squier, formerly United States minister to Central America, who was greatly interested in the economic extraction of these fibers, their cultivation, and application in the various arts for which their qualities render them so eminently suitable:

> All vegetable fibers used for textile purposes resolve themselves into three great classes—foliaceous fibers, cortical fibers, and capsular fibers.
>
> *Foliaceous fibers.*—These are obtained from what botanists call endogenous or monocotyledonous plants, or inside growers, which are best known to us in the herbaceous forms, such as the grasses, including the cereals, sugar-cane, and the common cane, as also the lily, the cat-brier, and all plants in which the leaves have parallel veins. Under and near the tropics the endogens are represented by the yuccas, the agaves, the plantains, and the great family of palms. These plants do not form a regular bark, show no signs of annual growth, and do not increase by continual additions to the outside of their stems, as in trees common to our climate. Their fibers are imbedded in the cellular tissue and pulpy matter of their stems and leaves, and in most, if not all, cases can be extracted by a purely mechanical process. The fibers known as Manila hemp, Sisal hemp, silk grass, &c., are obtained from plants of this class. It is only in tropical and subtropical regions that endogenous plants attain any great development, take arborescent forms, or yield fibers suitable for textile purposes. To an inhabitant of the northern temperate zone an endogenous plant of which the green leaves yield valuable fibers is a curiosity seen only in conservatories and botanical gardens.
>
> *Cortical fibers.*—These are obtained from what are botanically known as exogenous or dicotyledonous plants, or outside growers, and are contained in their bark or bast. They are often of great length, but little hardened, and with the exception of cotton are the most valuable produced in the temperate climates. Some of the plants of this class attain great size. A familiar example is the linden (bass or bast wood) of Europe and our own country, and the wild fig or banyan tree of the tropics. A great number, however, are herbaceous, such as most of the mallows (in which is embraced the cotton plant), a large portion of the *Urtica* or nettle (embracing the familiar hemp), the *Linacea* or flax family, and some varieties of the *Leguminosæ* or pea and bean tribe, such as the *Crotalaria juncea*, which supplies the *Sunn* or Bengal hemp. The stems of these plants consist of a woody core, surrounded by a sheath of fibrous texture, and the two are connected by a peculiar vegetable glue, which unites them in a solid stem. In the preparation of flax, hemp, china-grass, &c., the object is to remove this matter, and thus separate the useless stem from the valuable external sheath of fibers. * * *
>
> *Capsular fibers.*—These, as the name indicates, are obtained from pods or capsules. Cotton, a familiar type of this class, is found in the capsules of the *Gossypium* enveloping the seeds, and in nearly all cases closely adhering to them. * * *

FIBER-PRODUCING PLANTS.

ENDOGENOUS SPECIES.

Six orders of the endogens yield fibers which are commercially valuable, viz, the Agave or Amaryllis family, the Bromelia or pine-apple family, the Musa or plantain family, the Yucca or lily family, the Palm family, and the Pandanceæ or screw-pine family.

AGAVE OR AMARYLLIS FAMILY.

Many plants belonging to this family produce excellent fibers in great abundance, and are indigenous in all parts of tropical and inter-tropical America over a broad belt of at least 33° on each side of the equator, from Virginia on the north to Paraguay on the south. They are easily cultivated, hardy, and flourish equally in the richest and the most sterile soils. Indeed, in thousands of places where rocky, indurated, and sandy and arid soils prohibit every other kind of vegetation, the agaves find root and a vigorous growth. Several varieties are indigenous in the United States, such as the *Agave virginica*, which is found in the worst soils from the Potomac to the Mississippi, and the *A. vivipara*, which is found in Florida, and perhaps in some of the other States fronting on the Gulf of Mexico. It is, however, under the tropics proper throughout Mexico, Central America, the northern states of South America, and in the West Indies that the agaves are most abundant. * * *

The fibers extracted from the agaves differ widely in firmness and consequent value, although all are available for cloth, cordage, and paper. The fiber, it is said, also varies considerably with the age of the plant, being most pliable and easily worked if taken when the plant is young. * * *

Superficial writers and travelers have caused great confusion and uncertainty in respect of the agaves, by confounding the different species, and their contradictions have much embarrassed practical men in their calculations and efforts for utilizing them. This uncertainty and confusion have been greatly increased by the different and difficult names (generally Indian) by which the agaves are distinguished in the various parts of the continent. In Mexico the different varieties are called maguey, maguey de pulque, metl, cabulla, hennequin, sosquil, &c.; in Yucatan and Central America, hennequin, cabulla, pita, yashqui, sacqui, &c.; in Cuba, maya, hennequin, pita, piñon, &c.; in Venezuela and New Granada, cocuy, cocuiza, &c.; and in Brazil, grawatha, &c. Great confusion also exists in the names of the fibers extracted from the agaves and those taken from the bromelias, or plants of the pine-apple family, which are often confounded, even in the countries where they are produced. The following descriptions, however, will serve to correct, in part at least, some of the mistakes in these respects: * * *

AGAVE SISILANA.

Agave sisilana is so called from the city of Sisal, in Yucatan, whence the fiber, extracted slowly by hand, has found its way to market under the name of Sisal hemp or grass hemp. This plant, called sosquil in Mexico, and cabulla in Central America, is indigenous in every part of tropical America, and may be cultivated with the greatest ease to any desirable extent as well on the very stony surfaces of the interior as on the very sandy soils of the coast. There are two varieties, distinguished in Yucatan as the yashqui hennequin, which produces the best quality of Sisal hemp, and the sacqui hennequin, which gives the greatest quantity. In Central America the fiber of both these varieties is called cabulla, and is used for cordage, while the fiber from the *Bromelia sylvestris*, distinguished as pita, is fine, and used for thread and cloth.

Plate XIII represents the yashqui variety of the *Agave sisilana*, with lower leaves cut away for use. In Plate XIV, Fig. 1 represents a freshly cut leaf from this plant. Fig. 2 represents the same leaf with its fibers exposed from the point *a a* by means of the triangular wooden scraper (Fig. 3) which is used by Indians in removing the pulpy part of the leaf.

Fig. 4 is a notched wooden instrument, used in splitting the leaf into strips, five or six in number, each of which is afterwards worked by the triangular scraper, which is used after the manner of a currier's knife. Without quoting the full text, the following is the substance of Mr. Squier's quotation from the Illustrated Report of the Great Exhibition in New York in 1853 concerning the cultivation of *Agave sisilana*; The young plants are set about 12 feet apart, preferably in stony or sandy soil, and for two years require some care and labor to destroy the weeds; shoots 3 feet high, when transplanted, yield in two years. Cutting commences with lower leaves in third year, and is repeated every four months. A strong plant will yield from 25 to 100 leaves a year for five to ten years. One hundred average leaves are estimated to yield 10 pounds of fiber. The most productive leaves are from the fourth cutting. Each plant throws out five to ten shoots every two years from its roots, which, with a single exception, are transplanted; the single exception being made to take the place of the parent stem, which is cut down when it has become of less value than the shoot. If permitted to grow, the parent eventually shoots up an immense flower stalk 30 or 40 feet high. * * * The methods of extracting the fiber, practiced by the natives of Yucatan are of the most primitive character. The leaves are laid on a board held against the breast, and the skin and pulpy matter that inclose the fiber scraped away with triangular wooden scrapers (Fig. 3, Plate XIV), about 12 inches long and 3 inches thick. Implements sometimes vary considerably in form and method of using, but are always of the rudest construction and designed to operate on the same general plan, that of scraping the fibers as free as possible from the investing matter, ready for washing and drying in the sun.

AGAVE MEXICANA.

Agave mexicana, or maguey, sometimes called pulque agave, is the plant which yields the sweet liquor called pulque, which, when fermented, becomes intoxicating, and is drunk by the Mexicans instead of wine, beer, and cider. The fiber of this variety of agave is said to be coarser than Sisal hemp, but still valuable for many purposes, especially paper and brushes. It is for the juice, however, that it is principally cultivated in Mexico.

The plants are set in rows about 5 feet apart. When the hampe, or central stem, which often attains the height of 40 or 50 feet, is on the point of efflorescence, it is cut out and a hollow scooped for receiving the sap. This keeps running for two or three months, the reservoir being emptied three or four times a day.

The yield from a vigorous plant is about 400 cubic English inches per day, or for the period of yield from 40,000 to 70,000 cubic inches, or from 200 to 300 gallons! This enormous product is all the more remarkable from the fact that the maguey plantations are generally in arid ground, and frequently on ledges of rock scarcely covered with vegetable earth. The plant has firm, vigorous leaves, and is neither affected by drought, wet, hail, nor by the excessive cold which prevails in the higher cordilleras of Mexico. It perishes after efflorescence, but an infinity of shoots then spring from the decaying roots.

Plate XV represents this plant with the flower stalk cut down and the stump scooped out for a sap reservoir.

AGAVE AMERICANA.

This plant, which has been naturalized in the south of Europe and Algeria, is often confounded with the maguey, or *Agave sisilana*. Its flowering stem, when the plant is vigorous, rises to the height of 40 feet or upwards, and throws out branches on every side, like those of a candelasbrum, so as to form a kind of pyramid, each branch supporting a cluster of greenish-red flowers. These give place to bulbous seeds, which, when planted, spring up rapidly and luxuriantly. The original plant, however, dies. The time of flowering varies with localities and climate. An erroneous notion is that it flowers only once in a hundred years. Hence the popular name of Century Plant.

Plate XVI represents the plant in full flower. The fibers from its leaves closely resemble those from the maguey.

AGAVE VIVIPARA AND AGAVE VIRGINICA.

Both these varieties are indigenous in the United States from Virginia to Florida. They resemble each other closely, and can only with difficulty be distinguished. The former sends out no shoots from the roots after flowering, like the maguey, but is only propagated by its seeds. Little is said of these two varieties of the agave as to the character ot their fibers, but from that little and their similarity to other fiber-producing plants of the same family, it is reasonable to assume that they are also useful and valuable.

Plate XVII represents the *Agave virginica.* Mr. Squier speaks of specimens of fiber from the *Agave vivipara* of "admirable quality," having been shown at the great Exhibition of 1851.

Mr. P. L. Simmonds, F. R. C. I., in an article on "Fibers and Cordage," says:

> All the species of agave, and particularly *A. vivipara*, familiarly termed silk grass, furnish a white and somewhat harsh and brittle fiber, possessing, however, useful properties.

Also, concerning agave fiber in general:

> Under the name of Mexican grass we import into the United Kingdom about 19,000 hundred weight of agave fiber, cut short and cleanly prepared, which is used as a substitute for bristles in cheap nail and other brushes. It is locally called itzle, and is very extensively produced in the Isthmus of Tehuantepec and the higher lands of Mexico. One man can prepare 4 or 5 pounds of fiber per day.

As evidence of the confusion that exists among others than "superficial writers" as to the names of the fibers of the agaves and bromelias, it is noticed that "in the year 1857 Chief Justice Temple, of Balize, or British Honduras, read a paper before the Royal Society of Arts of London on the resources of that country," in which he referred to the bromelia fiber as being called "istle" by the Mexicans and "silk grass" by the creoles of British Honduras, giving a full description of the plant and its fibers, and that, in the subsequent discussion of the subject-matter of Justice Temple's paper by the leading members of the society, Mr. P. L. Simmonds referred especially to what had been said of the bromelian fiber, and without taking exception to the local names of "istle" in Mexico and "silk grass" in Balize as misnomers; yet, in 1877, as has been seen, the same authority refers to the fibers of the agaves in general as being locally called "itzle" in the "highlands of Mexico and the Isthmus of Tehuantepec," and to that from the *Agave vivipara* especially as being called "silk grass."

The natives of Mexico and Central America no doubt apply the term "istle" indiscriminately to the fibers of both bromelias and agaves. This is not surprising in view of their striking similarity, the obliteration of distinguishing characteristics due to cultivation, and the wide variation in the quality of the fiber due to age, both of the plant and of the individual leaves on the plant. The coarse fiber of the brushmaker's "tampico," which is imported under the name of istle, is no doubt obtained from the exterior leaves of certain varieties of both bromelias and agaves, and perhaps from some of the yuccas also. Most writers, however, refer to the "istle," "ixtle," or "itzle" as the fiber of the *Bromelia sylvestris.*

BROMELIA OR PINEAPPLE FAMILY.

The plants of this family are all indigenous to the continents and islands of America, and many of them yield fibers of excellent quality. One variety, that producing the delicious fruit known as the pineapple (*Ananassa sativa*), has been introduced into the East Indies, where its fibers have been extensively used in the manufacture of the delicate fabric called piña (pronounced pinya), as also for cordage, &c. The piña fabric, more delicate in texture than any other known of the vegetable kingdom, is woven from the untwisted fibers of the pineapple leaf after they have been reduced to the greatest fineness. In order to produce a continuous thread the selected fibers are glued together at their ends, forming an unbroken line, by which means the even character of the fiber is produced.

The fibers of the *Bromelia sylvestris*, known in Mexico as "istle" or "ixtle," and in Central America as pita or piñuella, are probably more valuable in every sense than those from any other tropical plant, and it would seem may be produced more readily than those of *Agave sisilana*. * * * * This plant is self-propagating, and if left to itself in an open field will soon cover the ground. In Central America, but particularly in Nicaragua, it is so abundant in the forests as to be a serious obstruction to the passage of man or beast.

Fig. 5, Plate XIV, represents a leaf of this plant showing the difference between it and that of the hennequin (*A. sisilana*).

The following concerning the "istle," or *Bromelia sylvestris*, is Mr. Squier's quotation from a report on the Isthmus of Tehuantepec by Major Barnard, U. S. A.:

> Among the spontaneous products of the isthmus is the *Bromelia pita* or ixtle, which differs in some respects from the *Agave americana* of Europe, the pulque maguey of Mexico, and the *Agave sisilana* of Yucatan. Of this prolific plant there are numerous varieties, all yielding fibers which vary in quality from the coarsest hemp to the finest flax. It is indifferent to soil, climate, and season, and the simplicity of its cultivation, and the facility of extracting and preparing its products, render it of universal use. From it is fabricated thread and cordage, mats, bagging, and clothing, and the hammocks in which the natives are born, repose, and die. The fibers of the pita are sometimes employed in the manufacture of paper; its juice is used for caustic for wounds, and its thorns serve the Indians as needles and pins. The place generally selected for its cultivation is a thick forest, from which the small undergrowth is removed by cutting and burning. The roots of the old plants are then set out at a distance of from 5 to 6 feet apart, and at the end of the year the leaves are cut and "rasped." When the ixtle is young its fibers are firm and white, but as it increases in age they become longer and coarser. In this manner it is easy to select the quality of fiber required. In a wild state its thorns are very numerous, but by cultivation they are diminished, both in size and number, and in many instances there are none at all. Even with the imperfect instruments used in cleaning the leaves, four or five pounds of fiber per day is only a fair average for the labor of a man.

Plate XVIII represents the *Bromelia sylvestris*, and Plate XIX represents the *Bromelia ananas*. The Annual of Scientific Discovery for 1870, under the title "Little-known fibrous plants," supplies the following concerning the *Bromelia sylvestris* and its fiber:

THE IXTLE FIBER.

> The following is a letter from the Hon. J. McLeod Murphy to the Commissioner of Agriculture, accompanied with three skeins of the ixtle fiber, *Bromelia sylvestris*, each produced from a single leaf, of which a single plant might average twenty. We extract the substance of this letter from the report of the Department of Agriculture for May and June.
>
> "First of all, before I describe the plant and the method of its cultivation, I beg to call your attention to the extraordinary length and strength of the individual fibers, their susceptibility of being divided almost infinitesimally without breaking, their flexibility without kinking, and the readiness with which they receive and hold vegetable or chemical dyes without being impaired. Since my return from Mexico I have had little or no opportunity of testing this plant practically; but some samples, such as I send you, were given to an old and experienced maker of fishing-tackle, and he does not hesitate to pronounce the ixtle fiber as superior in every respect for the manufacture of trout and other fishing lines, not only on account of the readiness with which it can be spun and its extraordinary strength, but its perfect freedom from kinks when wet. The only secret, if there is one, consists in the preliminary precaution of boiling the fiber (as you see it here) before twisting it. In this one respect it will supersede the use of silk. Apart, however, from its use as thread, I hazard nothing in saying it forms the best paper-stock that can be obtained. I speak now with reference to the imperfect, withered, rejected, and dried leaves from which the fiber cannot be conveniently extracted by the indifferent means that the Indians employ. Although I have no samples of the paper made from this source just now at hand, yet I can assure the Department that several magnificent samples of paper for banking and commercial purposes have been made by manufacturers in the Eastern States from the dried leaves of the ixtle plant, brought from the neighborhood of Tobasco.
>
> "The samples of fiber I send with this were obtained by the most primitive means, namely, by beating and at the same time scraping the leaf of the plant (in a green state) with a dull machete. After the removal of the glutinous vegetable matter it is

combed out and rubbed between the knuckles of the hand until the fibers are separated. The next step is to work it in tepid water and bleach the skeins on the grass. This is the method pursued by the Indians on the Isthmus of Tehuantepec, and the average product for the labor of a man is from 4 to 5 pounds per day. It is scarcely necessary to tell one so well informed as yourself that this spontaneous product is the *Bromelia sylvestris*, which differs in some respects from the *Agave americana*, the *Pulque de maguey*, and *Agave sisilana* of Campeche, a difference arising solely from soil and climate influences.

"The name *ixtle* is given to that species which is characterized by the production of the long fiber, and chiefly because the leaf being shaped like a sword, has its edges armed with prickles, similar in fact to the weapon formed from *itzle* or obsidian, used by the Aztecs. Hence the term. The *pita*, on the other hand, although obtained from a variety of the same plant, is a coarser and shorter fiber which grows in the *tierras templadas*. The name comes from the word *pittes*, which is given to the plantations of the pulque plant in the uplands of Mexico. But the peculiarity of ixtle is that it grows almost exclusively on the southern shore of the Mexican Gulf, or in what is known as the '*sota vento*,' that is to say, between Alvarado and Tobasco, and extending as far inland as the northern slopes of the dividing ridge which separates the Atlantic from the Pacific. The points generally selected for its cultivation are the edges of a thick forest, from which the small undergrowth is removed by cutting and burning. The roots of the plants are then set out at a distance of 5 or 6 feet apart, and at the end of a year the leaves are cut and 'scraped.' The chief object is to obtain a constant shelter from the rays of the sun, which would otherwise absorb the moisture, and so gum the fibers together as to make them inseparable. The average length of a leaf is 6 feet, and the time to cut it is clearly indicated by the upward inclination it makes. In other words, the radial leaves cease to form curved lines with their points downwards but stiffen themselves out at an angle as if to guard the source of efflorescence. When the *ixtle* is growing the fibers are fine and white, but as it grows in age they become longer; and in a wild state the thorns are very numerous, but by cultivation they are diminished both in size and number, and in many instances there are none at all. * * * But as yet no mechanic has succeeded in devising a means of effectually extracting the fiber, and until this is done I presume that its real commercial value will remain unappreciated. * * * You will readily discover the superiority of the ixtle over the *jenequin* of Cuba, or the hemp which comes from Sisal and Campeche."

Mr. Squier, in the introduction to his work on "Tropical Fibers," refers enthusiastically to a "process" and a "machine" patented by Mr. J. E. Mallory and Mr. G. Sanford, respectively, as likely to greatly increase the supply of tropical fibers, to open new fields for their application, and to "revolutionize on both continents the present mode of production." But as this was written in 1861, and as the "process" and the "machine" did not seem to be known in 1870 to a man so well informed as the author of the foregoing letter, it is reasonable to suppose that Mr. Squier's anticipations have not been fully realized.

The great demand for machinery for this purpose has, however, stimulated inventive talent, and a great number of patents have been granted for fiber-extracting machinery since 1861 (several to the same Mr. Sanford referred to above), some of which devices must have proved vastly superior to the primitive processes of the natives, judging from the quantity of this fiber which appears in commerce, and the great number of uses to which it is applied. Instead of being limited in its use to the rude manufactures of the natives, it is exported in large quantities to the manufacturing countries where it enters into a great variety of textile fabrics, cordage, &c. In this country and England, at least, many tons of the coarser fibers are annually consumed in the manufacture of brushes. According to the United States Treasury report for the year 1880, there were imported into the United States alone of the fiber called istle:

	Custom-house valuation.
To New York, 973,219 pounds	$55,389
To New Orleans, 500,640 pounds	30,545
To other ports, 656,212 pounds	41,227
Total, 2,130,071 pounds	127,161

There are many other endogenous plants which yield fibers principally valuable for cordage and woven fabrics, though used to a limited extent in the manufacture of brushes of one form or another. Among these are noticed several varieties of the great family of palms and a few of the yuccas or lilies. Of the former, the palm, known to science as *Arenga saccharifera* (Plate XX) is worthy of mention as the source of supply of *ejoo fiber*, or *gamuti*, as it is sometimes called. The tree grows from 20 to 30 feet high, and is surmounted by a thick crown of leaves. The fiber is produced by the natural splitting of the leaf-stalks into hair-like filaments, which hang in tangled masses from their bases, entirely surrounding the trunk. This naturally-produced fiber is noted for tenacity and durability, and for resisting moisture, this latter quality rendering it especially valuable for ship's rigging. The arenga palm is properly an East Indian plant, but a product very similar to *ejoo fiber* is obtained in tropical America from a variety of the palm known to the botanist as *Attalea funifera*, and from which piassava, monkey grass, or para grass, is obtained in the same way as *ejoo fiber* from the arenga palm. The two trees resemble each other, though the American palm is much more stately and elegant than its East Indian brother. Its crown of pinnated leaves sometimes rises 20 feet above the top of the trunk. The fibers become detached by a natural process from the petioles of the leaves, and hang down around the trunk in tufts several feet in length, hence the name *funifera*. The fibers are round and stiff, and in some cases as thick as rye straw. Great quantities of this fiber have been consumed in England in the manufacture of brushes and brooms, especially brushes for the street-sweeping machines of London. The juice of the arenga palm, when evaporated, yields sugar, and when fermented an intoxicating liquor, sometimes distilled into a kind of brandy called arrack. Each tree yields 4 or 5 pounds of fiber, besides a considerable quantity of sago.

Coir is the fiber of the cocoanut husk, and is obtained by soaking the husks in water for several months, or until they are quite soft, then drying them in the sun, and finally beating them with sticks or clubs until the woody substance is all pulverized and separated from the fiber. It is used chiefly for cordage, and for this purpose there is said to be no superior material. The East Indies are the principal source of supply, and from thence England imports annually several millions of pounds.

Of coir and coir rope, about 9,000,000 or 10,000,000 pounds are annually shipped from India. Much is prepared in Ceylon, but Cochin is noted as the port of shipment for the best quality of yarn, and many thousand hundred weight are annually exported from there. In 1870 we imported from the East 168,544 hundred weight of cable yarn of coir, valued at £177,956; 11,407 hundred weight of coir cordage, valued at £13,547; and 1,105 hundred weight of coir fiber, value £24,347. Probably the last named was intended for making matting and brush fiber, &c. The produce of fiber from the husk of one nut sometimes reaches 2 pounds in weight.*

THE LILY FAMILY.

Of the fiber-producing yuccas five varieties are indigenous in Mexico, Western Texas, and New Mexico. The fibers are obtained from the leaves in the same manner as those from the bromelias and agaves. Of the five native American varieties the *Y. gloriosa* and *Y. aloifolia* (both popularly known as Spanish bayonet), Adam's needles, petre, dwarf palmetto, &c.), and *Y. filamentosa* (sometimes called silk grass, Eve's thread, &c.), are referred to by most writers on the subject as conspicuously valuable fiber-producing plants. The fibers are very similar to those from the bromelias and agaves. (Plates XXI, XXII, XXIII.)

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* Fibers and Cordage, page 155.

EXOGENOUS SPECIES.

Of the exogenous plants producing cortical fiber, the urtica or nettle, the malva or mallow, and the tilia or lime-tree families are the most important. Of the fiber of the nettle family, common hemp is a good example. The fiber known to commerce as brown Indian hemp is the product of the mallow, called botanically *Hibiscus canabinus*, which flourishes in India. Jute, or jute hemp as it is sometimes called, is a representative fiber of the lime-tree family. Prominent in this family is the linden (commonly called bass or bast wood) tree, the inner bark or bast of which is tough and fibrous, and used in Europe for making mats, brushes, &c. Jute hemp is obtained from the inner bark of the *Corchorus capsularis*, a plant native in India, and found occasionally in Brazil. As to machines for the extraction and dressing of vegetable fibers, there is a great number and a great variety in use, but the scope and purpose of this article scarcely require the introduction of drawings and descriptions.

For those, however, who may desire to investigate the subject further, reference is made to the following list of patents issued from the United States Patent Office between the years 1853 and 1880, supplied through the politeness of Thomas D. Stetson, esq., solicitor of patents, 23 Murray street, New York:

Pownell, 1853, No. 9650.
Knowles, 1854, No. 10518.
Burke, 1857, No. 17420.
Sanford, 1861, No. 31479.
Patrullo, 1863, No. 38330.
Patrullo, 1867, No. 61244.
Henton, 1867, No. 68363.
Harkell, 1867, No. 63044.
Sanford, 1868, No. 84070.
Adamson & Simonin, 1871, No. 117852.
Adamson & Simonin, 1872, No. 126006.
Favier, 1880, 226506.
Sanchez, 1879, No. 221365.
Southmayde, 1879, No. 213950.
Courtenay, 1879, No. 217448.

HORSE-HAIR.

Horse-hair of commerce is obtained from the tail and mane, the former being usually longer and stouter, and chiefly used for textile purposes. Only the shorter and inferior horse-hair is used by brush-makers. All above 18 inches is used for weaving, and all below is dressed and curled for the upholsterer's use, or sold straight to the brush-maker. It is an excellent material for many kinds of brushes, especially those designed for rubbing and polishing smooth surfaces, as of leather. Solid horse-hair shoe-brushes are said by some to be superior to those of the best quality of bristles. It is also used for dusting-brushes requiring longer and more pliable filaments than bristles. Ixtle fiber, by dressing and dyeing, is made to closely resemble horse-hair, and is frequently used as a cheap imitation or substitute. Considerable quantities of domestic horse-hair are found in the markets of the United States, much of which comes from Texas. It is mostly short, and used chiefly for upholstery and brushes. It is separated into colors by hand, combed or hatcheled, assorted according to lengths, and tied into bundles of one or two pounds of the short hair, and more of the longer. The colors are white, gray, and black, very little, however, being white. The lengths are 6 to 10 inches, 10 to 18 inches, 18 inches, and 18 to 25 inches.

Imported horse-hair (tail-hair) is chiefly used for weaving. The principal sources of supply are the Argentine Republic, Brazil, Uruguay, France, England, and Germany. For brushes horse-hair is cut into lengths and drawn, or set, in the same manner as bristles. Short hair from the mane (frequently mixed with long hair from the tufted tails of neat cattle) is spun and twisted into a kind of cordage, which in the Western States and Territories is used for lariats. It is also woven into saddle girths or cinchas, for which purpose it is conceded to be superior to any known material, unless some of the tropical fibers referred to in the foregoing are found to possess equal excellence; which is not likely, unless the relative cost of the two materials be taken into account. Hair girths have been strongly recommended for the artillery and cavalry service, and for pack-saddles; but doubt has been expressed whether, in case of adoption, the demand for material might not exceed the supply. Of this, however, there would seem to be little probability. Of the amount of horse and other hair suitable for such purposes produced within the limits of the United States, no statistics are at hand. But of imported hair, Treasury reports for 1880 furnish the following:

Country.	Horse-hair used for weaving.		Hair of all kinds not elsewhere specified.	
	Pounds.		*Pounds.*	
Argentine Republic	1,278,157	$215,846	597,178	$98,375
Brazil	264,925	44,414	234,276	51,746
France	26,626	5,439	583,782	48,000
Germany	58,840	24,724	583,782	120,605
England	193,780	117,116	468,217	71,272
Central American States	....	....	80,262	11,287
Scotland	....	....	14,860	2,441
Nova Scotia and New Brunswick	2,811	368	1,255	135
Canada	120	8	27,589	3,634
Mexico	7,268	1,370	199,322	35,594
Netherlands	....	....	16,671	3,980
Cuba	3,075	472	3,572	590
Venezuela	....	....	55,224	10,431
Belgium	....	....	59,517	14,199
Uruguay	14,298	2,875	435,722	75,200
Total	1,849,900	412,682	3,048,520	547,439

WHALEBONE.

Whalebone or baleen, is a horny substance consisting of fibrous laminæ, laid lengthwise along the upper jaw of the whale, overlapping each other "like shingles on a roof." The plates of baleen in the mouth of a full-grown "right whale" are often 10 or 12 inches wide at the root ends and four to six-tenths of an inch thick. They are longest at about the middle of the series and sometimes measure 12 or 15 feet. They taper from the root to the free end, and are curved somewhat like a scythe. Along the concave edge is a kind of hairy fringe, varying in length from a few inches to a foot and a half, and in size from fine horsehair to the coarsest bristles. The size and quality of both bone and fringe vary greatly with the kind of whale producing them.

Zoologically, whales, or mammalia of the cetacean order, are divided into two great families—"blowing" cetacea, so called from the habit of spouting water through the nasal openings or spiracles in the top of the head, and "herbivorous" cetacea (manati). The family of "blowing" cetacea is divided into two tribes—the tribe of whales (*Balæna*) and the dolphin tribe, distinguished mainly by the size and shape of the head.

The whale tribe (*Balænidæ*) is divided into the genus whale and the genus cachalot (sperm whale). The genus whale produces the baleen. The cachalot has none; but teeth instead, in the lower jaw only, which fit into corresponding cavities in the upper jaw when the mouth is shut. Finally there are two sections of the baleen-producing genus, the true whale and the rorquals.

Whales properly so called are the Arctic, Greenland or right whale (*Balæna mysticetus*), and one or two other species in the Northern Pacific and Antarctic Oceans. Among whalemen (according to the authority of one of them) "the more common species of the right whale are known as the Arctic bowhead, the Greenland bowhead, the northwestern whale (a species taken in what is known as the Kodiak ground, and in the Sea of Okhotsk, between 50° and 60° north latitude); the South Sea whale, captured south of 20° south latitude, and down to the southern ice barrier; the sulphur-bottom, taken on the European coast; the humpback and finback, caught almost everywhere; and the rorqual, the largest and most worthless of all." The great northern rorqual seems to be referred to and to monopolize the name, though the humpback, finback, and sulphur-bottom undoubtedly belong to that series.

Whalebone is white, black, or some shade between the two, and sometimes all in the mouth of the same whale. Arctic and Greenland whales or bowheads produce plates, which are termed variegated, having alternate streaks of black and white, the white, however, never extending the entire length of the slab, and very seldom through it, being limited to a thin layer on each side. The sulphur-bottom and the humpback have black bone, finbacks have nearly, white bone (the outer edges dark), with some slabs nearly, though rarely, if ever, wholly, black. It is as readily split as the black, but said to be more brittle when dry.

Bone from the Arctic whale is long, thin, smooth, and usually blue-black, though sometimes variegated. The specimen, of which Fig. 7, Plate XXIV, is a representation, was taken from the tip of an Arctic slab 10 feet long. Bone of the Greenland whale is like the Arctic, only more wavy, and fringe shorter. Bone of the Northwest whale is long and very thick, fully half an inch, of a muddy-brown color, and fiber very fine. That from the South Sea whale is like the last, except it is shorter. Sulphur-bottom bone is bright black, nearly as wide as long (6 to 36 inches), and has a very coarse fringe. Humpback bone is nearly a bright black, longer and narrower than the sulphur-bottom, but with as coarse a fringe. The finback has a short, white, or partially white, bone, with a coarse fringe. The last three bones are very porous, small holes or capillary tubes running nearly the whole length, and somewhat brittle when dry. Arctic, Greenland, Northwest, and South Sea bone is tough, elastic, fine-grained, and capable of taking a high polish.

Whalebone is split with gauged knives, after being softened in a steam or sand bath. It can be reduced to very small strips, smaller even than the samples delineated in Plate XXV, in which—

Fig. 1 represents long Arctic strips, two sizes, each about 5 feet long, Brushes, though varying widely in form and material, are, in general, of two kinds, simple and compound; the former consisting of but a single tuft arranged around the end of a slender "stock,"* or handle, and the latter of several tufts set into a stock in close proximity. The former embraces an almost endless variety of tools used for the most part in laying on colors, as well as many forms of brushes made of long hairs or fibers designed for dusting purposes. The latter class includes horse-brushes, most of those used for household purposes, and those employed about the person; in fact, nearly all that are used for removing dust and dirt from other objects, and those used for polishing surfaces by rubbing. The compound class is again divided into two varieties—"set" or "pan" work, and "drawn" work. Common floor-brushes and molders' brushes are types of the former, and horse-brushes and clothes-brushes of the latter. Drawn brushes are either "solid" or "penetrating"; a "solid" brush is one having all the fibers trimmed to the same length; a "penetrating" brush is composed of fibers of unequal length.

MANUFACTURE OF COMPOUND BRUSHES.

PREPARATION OF BRISTLES AND FIBER.

The process by which brush material is prepared for "drawing" or "setting," varies with the kind of material and the character of the brush to be made.

Tampico is generally fully prepared at the dressing factories, both "solid" and in mixtures adapted to the wants of most brush-makers. A few manufacturers, however, buy raw fiber and prepare it themselves, substituting hand for mill dressing. In either case the operations are substantially the same, hackling, dyeing, combing, cutting up, and mixing with other material.

Rice root requires little preparation other than cutting up and moistening, the latter to facititate the drawing and to prevent the breaking of the fiber in the process. It is clean and sufficiently well assorted when prepared for market.

Horse-hair usually comes to the hand of the brush-maker in assorted colors, well combed and bundled, and requiring merely to be cut into suitable lengths.

Whalebone, artificially split, needs only to be cut to lengths for "set" or "pan" work, but should be softened in a steam or sand bath to prepare it for "drawing." Fringe bone is prepared in nearly the same way as horse-hair, which it resembles.

Split quills require both combing and cutting to prepare them for "drawing"; they are rarely, if ever, used for "pan work."

TOOLS.

Bench-comb.—This tool is usually composed of about seventeen steel teeth, 6 or 8 inches long, set at intervals of a quarter of an inch or more in a wooden block which is secured to the workman's bench. (Fig. 1, Plate XXVII.) It is the most useful of all the brush-makers' tools. It is indispensalbe in a brush factory and is in constant use in handling all kinds of hair and fiber, in cleaning and mixing them, in "loosening up" bundles of bristles for "dragging," "butting down," "flagging up," &c.

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* Various names as "stock," "block," "back," "body," "tree," "handle," &c., are applied to this part of the brush. "Stock" seems most appropriate and is generally used. Bristles, &c., are also called "stock." Whether the fibrous or solid part of the brush is referred to can be readily determined by the context.

Shears.—Shears of a peculiar construction, and especially designed for the purpose, are used for cutting up all kinds of stock when the cutting precedes the drawing. When cut after drawing, it is done with the trimming shears. The former instrument somewhat resembles that used by tobacconists for cutting up plug tobacco, except that the lower blade is sharply curved, forming a hollow into which the fibers are laid to prevent their spreading out and being cut into unequal lengths. The lower blade is short and has flanges on the lower side by which it is bolted to the bench. One end of the upper blade is pivoted to the lower, and the other end prolonged into a handle or lever. On the right side of the shears is an adjustable stop or gauge, fastened to the bench by a thumb-screw, to regulate the length of the cuttings. (Fig. 2, Plate XXVII.)

Size stick.—As already explained, bristles are graded in the market by their lengths in inches and fractions of an inch according to the American method, or by numbers corresponding to certain lengths as in the French. Brush-makers, however, have a conventional standard of measure called a "size stick," by which they designate lengths of paint brushes, and lengths of stock when dragging it to sizes. It is usually made of some hard wood in the form of a truncated pyramid with chamfered corners. (Fig. 3, Plate XXVII.) Across one face a horizontal line is marked 2¼ inches above the base. Immediately above this line is a row of nine dots in black, or some color readily distinguished from that of the surrounding wood. When a bundle of bristles reaches from the bench on which the size stick stands to this line, or when a paint brush is composed of bristles of the same length, either is designated as No. 9. The numbers on the scale decrease by units as the lengths increase by regular quarter-inch gradations from No. 9 (9 dots) to No. 1 (1 dot), after which the regular quarter-inch increments are designated by a number of naughts marked above the lines, but in an inverse order, ranging from one to eight. Bristles or brushes longer than No. 1 are designated by so many naughts up to "8–0," above which the lengths are expressed in inches.

Engine-comb.—Sometimes to make brushes requiring extra stiffness the brush-maker assorts his bristles by a process that separates them according to thickness and stiffness, as dragging does according to length. This process is called "engining," and the instrument used an "engine" or "engine-comb." This "engine" is merely a comb composed of a row of round, sharp-pointed, accurately-spaced steel teeth, usually set in a plug of solder cast into a wooden stock which may be screwed down to the bench. The comb is from 12 to 15 inches long, and the teeth rather more than 2 inches high. There are 3 sizes or numbers, No. 1, No. 2, and No. 3, No. 1 being the coarsest and No. 3 the finest. The spaces between the teeth are uniform for the same size, and are accurately gauged by a standard for each, so that when bristles are drawn through them all above a certain size will be caught and held fast between the teeth. The No. 1 "engine" is calculated to extract only the stiffest of Russian bristles.

Stock to be "engined" is first carefully combed and mixed, then in quantities of a few ounces at a time spread evenly across the surface of a long, narrow, and very stiff brush, and pressed in among the bristles with a straight-edge. A second and similar brush is then applied to the first, and the two driven together, holding the bristles between them with the roots projecting on one side and the flags on the other.

The workman taking the two brushes by the ends, and holding them parallel to the comb, presses the root ends of the bristles down between the teeth. By pulling the brushes horizontally away from the instrument the thick hairs are left sticking between the teeth and the thin hairs between the brushes. (Fig. 4, Plate XXVII.) Formerly when shoemakers and other leather-workers used bristles instead of needles to tip their waxed threads, those suitable for the purpose were selected by this process and called "shoe-hair," and by this name the bristles extracted with a No. 1 engine are still known.

BORING THE STOCK.

The stock of a "drawn" compound brush is usually composed of two parts, the body, in which the tufts are inserted, and the veneer or back which serves merely for a finish. When properly bored, the holes in the body do not extend entirely through with full diameter, but beyond the depth to which it is desired to insert the tufts, they are reduced to a size only sufficient to admit the loop of the drawing wire.

The boring is generally done with a single bit or drill and in one operation, a gauge or stop regulating the depth of the hole and permitting only a small central point of the tool to penetrate through. In well made brushes the tufts fill the holes snugly, and are drawn down firmly against the shoulder of the counterbore. This part of the work, however, being hidden by the veneer is frequently executed more with a view to profit of the manufacturer than to excellence and durability of the brush. To facilitate "drawing" the holes are too frequently bored through full size; and to economize material an insufficient number of fibers to make a snug fit in the holes are used. The holes are usually arranged in parallel rows conforming to the shape of the stock, those in the center perpendicular to the surface and those between the center and periphery inclining outward, the inclination slightly increasing with each successive row to give the proper splay to the brush. In factories not supplied with power the boring is done with a machine turned by the foot. (Fig. 3, Plate XXVI.) The brush body, with a perforated pattern or templet clamped to it to mark the position of the holes, is held by the workman against a wooden disk mounted on a slide having motion to and from the bit in the direction of its axis. While drawing the slide toward the bit the brush body is turned by the workman so as to direct the point of the bit into the holes in the templet, care being taken to keep the center of the pattern and the axis of the bit in the same vertical plane and to set the disk (the inclination of which is adjustable by means of a pawl and ratchet) at the proper angle for each successive row of holes. In large manufactories power machines are employed capable of boring fifteen or twenty bodies at a time and upwards of three hundred thousand holes in a day. A very suitable machine of this kind is built at the Gage Machine Works, at Waterford, N. Y., and is generally used in the large factories throughout the country. It consists of a row of bits with their axes all in the same horizontal plane, and their points all in the same straight line, mounted transversely on an iron frame, and driven each by a "quarter-turn" belt from a pulley on a long shaft running under the frame longitudinally. The brush bodies to be bored are secured, one in front of each bit, to the lower bar of a rectangular frame suspended from near the ceiling, and having a vibratory motion like the batten of of a weaver's loom. The rectangular frame is pivoted above to the arms of a rocking shaft and counterbalanced to allow a free but.

limited motion in a vertical direction, as well as one of oscillation, without disturbing the parallelism of the lower bar with the line passing through the points of the bits. The vibrations of the frame are produced by a number of cams on a shaft behind the lower bar and parallel with it. The cam shaft is driven by a belt from the shaft that drives the bits, and is started and stopped at will by a friction clutch operated by a treadle convenient to the foot of the workman. The lower bar of the vibrating frame carries on its side toward the bits a swinging board with hinges at intervals along the horizontal center line. The swing of the board is limited to a few degrees from a vertical plane, and is provided with notched arcs and latches by which it can be set at the necessary inclination. All the latches are connected so that they can be operated by a single lever in the middle of the frame. In front of each bit, with the center in the same vertical plane with its axis, a metal disk is attached to the swinging board. All the disks having their centers in the same horizontal line, being of the same diameter, and having teeth on their circumferences, are made to rotate together by means of a long rack running over their upper edges, when any one of them is set in motion. On the face of each disk are screw clamps for holding the brush body. The central disk, however, has clamped to it a perforated metal pattern or templet similar to that used with the foot machine. Over this disk, and concentric with it, is a raised rim of larger diameter which serves as a hand wheel by which the workman rotates the disks and raises and lowers the counterpoised frame. The bit in front of this central disk is replaced by a steel slide with a sharp point projecting beyond the points of the bits, but allowed a backward motion against a spiral spring or counter-weight. The brush bodies to be bored are clamped upon the disks so as to occupy the same position relatively that the pattern occupies upon the central disk, so that the steel point and the bits will enter corresponding points of the pattern and the brush bodies at the same time. When these arrangements have been completed the workman takes his seat in front of the central disk, seizes the hand-wheel with both hands, rotates the disks, or raises or lowers the frames until the hole in the pattern at which he desires to commence boring (usually one in the outside row) is opposite the steel point, then, having given the disks the proper inclination by means of the arcs and latches, he starts the cam shaft with his foot, and, as the frame swings forward, guides it so that the index enters the proper hole in the pattern. The index rod is driven back against the spiral spring, and the brush bodies are pressed against the bits which penetrate to an uniform depth, gauged by the "throw" of the cams, and exactly at the points indicated on the pattern. With each revolution of the cam shaft the disks are withdrawn from the bits, and before they are again driven forward the operator must have revolved and raised or lowered them so that the index will exactly enter the next adjacent hole in the pattern. To give the brush the proper splay, the swinging board is set at the greatest angle of inclination to the axis of the bits while the exterior row of holes is being bored. With each successive row the inclination is reduced, until at the center the board is vertical and the holes perpendicular to the surface.

The stocks of most *drawn* brushes are of wood or leather, though horn, bone, ivory, pyroxyline, vulcanized rubber, &c., are used to some extent, especially for hair, tooth, nail, and other forms of small brushes used about the person.

Stocks for *set* brushes are also generally of wood; they are bored in a similar manner to that described above, except that the holes are larger and never bored quite through.

SETTING AND DRAWING.

"Set" or "pan" work.—To make "set" or "pan" brushes the workmen sit around a table (Fig. 1, Plate XXVI,) in the center of which is a pan of molten cement. Each workman has at his left hand a pile of prepared stock, at his right hand a thread drawn through a hole in the table from a spool beneath, and in front a knife blade set in the table to cut off the thread. He holds in his left hand a small bundle of stock evenly butted down, and with the thumb and forefinger of the right hand draws from it a small "pinch" with a sufficient number of fibers to fill a hole in the stock, binds one end with thread, dips it in the hot cement, and inserts it with a kind of twisting motion. The cement is composed principally of pitch and resin, and is kept hot by a steam jacket around the pan when steam is available, otherwise by a lamp or small stove under the table.

"Drawn" work.—To make "drawn" brushes the drawers sit at a table, generally divided through the middle by a high longitudinal partition, and into sections, one for each drawer, by transverse partitions about three feet apart. (Fig. 2, Plate XXVI.) Each drawer is provided with a broad apron, spread out and fastened to hooks under the table to catch the fibers that fall from the hand in the process of drawing. Each section is provided with a pair of trimming shears on the right hand, and in the center a small vise attached to the edge of the table to hold the brush stock. A spindle driven into the table at a convenient place on the right hand holds a spool of drawing wire. The back of the brush stock is turned toward the right, and the wire is led to it through a leather loop nailed to the edge of the table. The material to be "drawn" is piled on the table convenient to the left hand. Half the number of hairs or fibers needed to fill one tuft hole are gathered between the thumb and forefinger, the same as for "pan" work, and passed into a bight of the wire previously pushed through the stock to receive them, and the wire then pulled smartly back, doubling the hairs and drawing them into the hole. This work is often done, with surprising dexterity and rapidity, by small boys and girls. Eight or nine thousand tufts have frequently been drawn by one girl or boy in ten hours. Several machines to replace hand work in drawing brushes have been patented in this country and Europe, but they are not in general use, and a description of them here would serve no useful purpose.

TRIMMING.

During the process of drawing each successive row of tufts is trimmed as soon as drawn with a pair of gauged shears attached to the operator's bench. (Fig. 2, Plate XXVI.) When the drawing is complete any unevenness in the length of the tufts is finally trimmed off with hand shears, or, as in some factories, with rotary shears, an instrument consisting of spiral blades attached to the surface of a rapidly revolving cylinder, and a stationary blade with its edge parallel to the elements of the cylinder. It is in many respects like an inverted lawn mower. It works very well when kept sharp, but if permitted to become dull, or if used unskillfully, is liable to pull out some of the fibers instead of cutting them off, particularly if the tufts have been loosely drawn.

VENEERING.

After trimming the veneer is glued on. To hold it in close contact with the body until the glue has set, the brush is compressed with screw-clamps between two flat pieces of wood, one against the veneer and the other against the ends of the tufts. As much pressure is applied as can be used without breaking down the fiber. This is found to be sufficient for leather stocks, which have their veneers further secured by stitching around the edge with thread or wire. Wood veneers require greater pressure, and the stock is left wide enough to permit the application of screw-clamps around the edge outside of the tufts. When the glue has set, the stock, if wood, is finished by trimming off the edge so as to leave only the required margin outside of the tufts and by polishing the veneer. Veneers are frequently made by gluing together pieces of wood of different colors so as to show all the colors in section when finished. In factories provided with power, much of the work of finishing wooden stocks is done by machinery; the edges are trimmed off with rotary knives and the veneer is ground into shape and polished on sand-paper wheels. Leather veneers must receive their ornamental finish before being glued on, leaving only the edge to be finally trimmed off and polished. The embellishment of leather veneers is chiefly limited to impressed or embossed devices and figures made with dies or stamps. Since the stocks of "set" brushes are not bored through, there is no necessity for a veneer, except when the material of the stock is not susceptible of a sufficiently elegant finish. After the pitch, in which the tufts were set, has hardened, the back of the stock is finished with whatever ornamentation may be desired, generally by polishing the natural wood, painting, varnishing, &c.; sometimes by veneering and inlaying other materials.

Some kinds of small brushes drawn in stocks of bone, ivory, &c. (such as tooth and nail brushes), are not veneered, but have the drawing wire concealed in grooves in the backs, which are finally filled with a kind of hard insoluble cement. Such brushes are also made by a process called trepanning, in which the tuft holes are arranged in straight parallel rows, and are not bored through, but terminate at their intersection with smaller holes at right angles, drilled in the edge of the stock and running longitudinally under each row of tuft holes. The drawing wire is introduced through these small holes and loops are pulled out through the tuft holes to receive the fibers, which are drawn double in the usual manner by pulling back the wire. When the drawing is complete the wires are cut off, the ends made fast, and the holes stopped with plugs of bone, ivory, &c., usually the same material as the stock.

GENERAL REMARKS ON THE MANUFACTURE OF COMPOUND BRUSHES.

Vegetable fibers and long hair for solid brushes are cut to lengths for drawing, with allowance for trimming to uniform length. Bristles for solid brushes, if procured already dressed, have only to be combed to separate adherent hairs and to bring them into parallelism, and then they are drawn whole, butts first, the drawer being careful to place them in the bight of the drawing wire, so that there will be no unnecessary waste from the butts when trimmed. The flags are then cut off with the trimming shears and either laid aside for other work requiring less stiffness or are drawn in the next adjacent row, making alternate rows of butts and flags. If the brush is designed to be extra stiff, only superior stock is used and only the butt-cuts. If raw bristles are used they must be dressed by processes already explained. Most bristles of foreign dressing (except the French) have more or less short stock mixed with the long in the same bundle, the longest and stiffest being on the outside as "casings." Such are termed "taper stock," in contradistinction to "draggings." Partially prepared stock of this kind for fine solid brushes should be washed and "dragged" to sizes, and white stock washed and bleached. Suitable sizes are then selected from the draggings to make the quality of brush desired, carefully combed, cut, and drawn as described.

Penetrating brushes, if of vegetable fibers, or mixtures of fiber and hair, are drawn from cut stock of unequal lengths, or, what is equivalent, from cuts of equal lengths, the fibers in the tufts being left, purposely, uneven at the ends, so that all are not doubled exactly in the middle. In either case the trimming must clip only the fibers projecting beyond the maximum length prescribed. Bristle brushes of this character are drawn from what is termed a "shake-up"; that is, from stock selected from several qualities, cut to the desired lengths, and then thrown into a box where it is thoroughly "shaken up" and mixed together. The brush is drawn from the mixture, and is trimmed and finished the same as those from other material.

All bristles, whether foreign or domestic, for fine penetrating brushes, if not already carefully dressed when procured, should also be washed and dragged before cutting up. If not washed, the brush will always appear to be full of dust and will soil whatever it is used upon. If not dragged, much of the solid portions of the long bristles will be sacrificed in order to cut off the flags of the shorter. The flags must always be removed for drawn work (as the presence of only a few in a brush perceptibly softens it), and this can only be done without waste by cutting up the dragged sizes separately. After the flags have been cut off, the remainder is cut into proper lengths, and a suitable mixture of selected cuttings is shaken together for the variety and quality of brush desired. It is, however, the custom with certain brush-makers, especially when self-interest is not promoted by economy of material, to cut up taper stock (like okatkas) after simply combing and "flagging up," the object of the latter operation being to even up the flags of the whole bundle, leaving the unevenness at the root ends, so that the flags of the long and short bristles may be cut off in one operation without unnecessarily shortening the long ones. By this process the best portions of all lengths are *theoretically* preserved. Bristles to be cut in this way are first combed in small handfuls to separate any that have become adherent, and to arrange them all parallel to each other, and then, being held loosely in the hand, the flags are struck gently against a smooth surface (usually a piece of board fixed vertically to the front of the bench near the comb), the combing and striking being repeated alternately until the flags of all the bristles, long and short, are supposed to have been struck up even with the soft end of the bundle. Though the success of the operation is largely dependent upon the skill with which it is performed, yet the theoretical object is never practically attained; either some flags of short bristles will not be cut off, or some butt-cuts will be too short for use and will be wasted. By this method there is a waste of 12 to 20 per cent. of weight in ordinary Russian stock long enough for two cuts for tufts seven-eighths of an inch high. By previously dragging the stock this waste will be considerably reduced and the finished brush improved.

It should be further remarked that for fine brushes, such as those used about the person, the root bulbs should be removed before cutting up, either by clipping with shears or by washing in bundles, with soap, on a flat stone. The former is preferable when the length of the stock will admit of it. Plate XXVIII represents the draggings from a bundle of "superior" 7-inch okatkas, weighing 15.7 ounces. The lengths and weights of the different sizes are marked on tags attached to each bundle, viz:

7-inch.	8—0	7—0	6—0	5—0	4—0	3—0
$1\frac{3}{8}$ oz.	$3\frac{1}{8}$ oz.	$4\frac{1}{4}$ oz.	3 oz.	1 oz.	1 oz.	$\frac{3}{4}$ oz.

2—0	1—0	No. 1.	No. 2.
$\frac{1}{2}$ oz.	$\frac{1}{4}$ oz.	$\frac{1}{4}$ oz.	$\frac{2}{10}$ oz.

These samples were prepared and presented by J. G. McMurray & Co., of Lansingburgh, N. Y.

The foregoing is a description of the processes of manufacture of the leading types of compound brushes, both "drawn" and "set," represented in the illustrated catalogues of the largest manufacturers. Many other methods are employed, however, mostly patented, and aiming to cheapen the brush rather than to improve it. By one of the most important of these processes is made a very serviceable and showy brush without the expense of boring and drawing. The stock is composed of vulcanized caoutchouc, in which the ends of the tufts are imbedded while it is in a plastic or semi-fluid state. It is formed in a mold, one side of which is engraved with ornamental devices for the back, and the other perforated with holes into which the tufts are inserted and left projecting into the interior of the mold to the depth it is desired to have them set in the stock. This material receives and retains sharp impressions from molds engraved with the finest lines and most intricate patterns, and is, in this way, susceptible of highly ornamental finish.

There is another form of brush in quite common use which cannot be properly classed with "set" or "drawn" work. This is a brush used for cleaning bottles, lamp chimneys, &c., and, in the military service, for wiping out the bores of small-arms. It is made by introducing bristles, cut to a uniform length, between two parallel wires and twisting these together until the bristles radiate spirally and form a nearly cylindrical brush. The bristles are arranged at right angles to the wires and are held by the middle. The bottle-brush sometimes differs from the simplest form of this brush by having the twisted wires which hold the bristles doubled over the end of a stick for a handle.

All the principal varieties of compound brushes, both "drawn" and "set," are represented in Plates XXIX, XXX, XXXI.

Most of the illustrations have been taken from the catalogues of John L. Whiting & Son, of Boston (132 Oliver street), Miles Brothers & Co., of New York (102 Fulton street), and Ilsley, Doubleday & Co., of New York (243 Pearl street).

HORSE-BRUSHES.

Resolution No. 6, Ordnance Memoranda No. 18, page 53, reads as follows:

> *Horse-brush.*—To have one body of stout leather, with Russia bristles, one strap for hand.
>
> The stitching around the edge of body to be with brass wire. The size to be that of sample submitted.

Figure 9, Plate III (same Memoranda) gives the dimensions of the sample above referred to as follows: Length, 8.5 inches; width, 4.6 inches; thickness of back, .45 of an inch; length of tufts, .80 of an inch.

Beyond the specified length and breadth of the "body" the drawing alone suggests its shape, in which it appears to be oval or nearly elliptical. There is no specification, however, relative to the manner of building up the body, to the number, size, and arrangement of the tufts, to the grade of Russia bristles to be used, nor to the manner of drawing, as to whether it should be solid or penetrating, all of which are important points seriously affecting the quality of the brush. Most horse-brushes found in the trade, whether drawn in wood or leather, are oval like the cavalry pattern. Another form with parallel sides and semicircular ends is, however, quite common; and some of these have been supplied to certain departments of the military service, and have been preferred by some to the adopted pattern. Whether its peculiar shape is considered one of its merits, or whether it is preferred for other qualities, is not definitely known. The fact, however, that the oval is the prevailing shape used in the large city stables where great numbers of horses are kept, is sufficient evidence that there is nothing in the shape to especially recommend it. A few examined specimens (unserviceable and nearly worn out) were composed of gray okatka bristles, with tufts about the same size and at the same distance apart as the cavalry pattern, but only three-quarters of an inch high. The stock was perhaps a little better than that supplied by the Ordnance Department for recent manufactures of the standard pattern, and this together with the reduction in the length of the tufts no doubt gave the brush a much stiffer feeling and a real superiority.

Leather bodies for horse-brushes manufactured for the trade are almost always composed of leather shavings pressed together with glue or rye paste into slabs $\frac{3}{10}$ to $\frac{3}{8}$ of an inch thick, and large enough to make three large-sized bodies. This material, made in varying thicknesses, and used for various purposes, is prepared in large quantities all over the country, in Boston, Lynn, Buffalo, Cleveland, Chicago, &c. A kind very generally preferred for horse-brushes is made by Joseph Gardner, Hudson street, Buffalo. The bodies are cut out in a stamping press, bored and drawn in the usual manner, and veneered with thin collar leather glued on and machine-stitched around the edge with stout waxed thread. They are said to be durable and to give satisfaction. The material is cheaper than any suitable leather in whole sides or scrap large enough for complete shapes for bodies, and if found suitable for the military service the substitution of it for the more expensive "stout leather" recommended might furnish a means of turning to profitable account a large amount of small scrap otherwise almost valueless. There is, however, always available at the arsenals where leather is used in the manufactures, a large quantity of scrap of better quality than shavings, quite as serviceable for the purpose as stout leather and much cheaper. Perhaps sufficient of this latter will be found to make a resort to pressed shavings unnecessary. Of course it will cost more for labor to build up the body of thin layers to the required thickness, but this increase, it is believed, will be more than compensated by the less cost of the material. Bodies of "stout leather" .45 of an inch thick, must be composed of at least three thicknesses, for the portion in which the bristles are drawn should be at least .35 of an inch thick to give the necessary support to the bristles, and must necessarily be composed of two thicknesses. The veneer, *always necessary*, will form the third. To make the best brush-body possible, under the specification, without regard to cost, two thicknesses of the best quality of sole leather, split to a uniform thickness of .175 of an inch, should be used for the body, and one thickness, reduced to .1 of an inch, for the outside piece or veneer.

An examination of several unserviceable horse-brushes, manufactured and issued to the cavalry since the pattern of 1874 was adopted, shows that the number of tufts varies, the greatest number found in one brush being 476. The holes are about .09 of an inch in diameter, with a space of about .15 of an inch between. The sample brush referred to in the specification is not at hand for examination, and the number and size of the holes in it are not known. It is probable that these details have never entered into the articles of agreement with manufacturers, who, in the absence of specific requirement, may have used their discretion to promote selfish interests, which often lie in the direction of smaller holes, fewer tufts, and more brushes, especially since the Government has habitually supplied all material and paid liberally for the making.

The arrangement of the tufts in all brushes, pattern of 1874, manufactured for the military service has, as far as known, been almost universally that of parallel rows conforming to the shape of the body, and as nearly in the quincunx order as possible on curved lines.

Oval brushes are, however, frequently seen with tufts arranged in straight lines crossing each other at various angles, and generally bordered with one or more continuous rows to give the margin of the brush a more even appearance. In one (patented) arrangement the tufts are drawn in a rectangular pattern, with those in each pair of adjacent rows inclined towards each other for mutual support. These, especially the latter, are not satisfactory, open spaces being left between the tufts for the accumulation of dirt, and the brushes being less durable than those in which the tufts mutually support each other on all sides. The same objection may also be properly made to brushes with tufts less than .1 of an inch in diameter and .15 of an inch apart, especially when weak bristles are used and the tufts are .8 of an inch high. With any kind of stock the tufts should be larger and nearer together than in those brushes hitherto made for the cavalry, and if the stock is weak they should be shorter. The height of the tufts in the adopted pattern being fixed at .8 of an inch, the use of an excellent quality of bristles becomes a necessity if the specification in this particular is followed; for with the best imported stock horse-brushes are rarely made with tufts more than one inch high. The number of tufts composing the brush will of course be limited by its size. For an oval brush 8.5 inches long and 4.6 inches wide it is believed there should not be less than 485 or 500. They should be at least .13 of an inch in diameter, and the spaces between them should not much exceed that measurement.

Both solid and penetrating brushes are found in the market, but fewer of the former than of the latter. Penetrating brushes are generally preferred, though the solid are said to be more durable.

The following are memorandum notes of opinions, &c., gathered from a few prominent manufacturers: Hiram Averill, of Boston, who makes a grade of horse-brush styled "454," oval pattern, army size, says it is the shape universally approved in the large city stables; that it wears better than those with wide semi-circular ends; that the wear upon the curry-comb does not depend so much upon the construction of the brush as upon the quality of the material in it and the manner of using it; that at the Metropolitan street-car stables the hostlers all wear out the "leather-backed" horse-brush in the middle instead of at the ends, as do most cavalrymen. He says the solid brush costs less to draw than the penetrating; is not so "keen" when new, but more durable; thinks bristles show more for their quality when drawn solid, butts and flags in alternate rows; that the "shake-up" is more economical, especially when the bristles contain the usual proportion of extra long (say 10 per cent.) which furnish three cuts. He also says the cost of the brush would be greatly increased if made of engined stock, because the "soft hair" or residue, after the extraction of the "stiff," is only equal to a very low grade of stock. A grade of horse-brush made by him of superior engined okatka stock sells in the market for $36 per dozen and upwards.

John L. Whiting & Son, of Boston, though they do not make horse-brushes a specialty, concur in the foregoing opinions. Austin & Fellows, of Boston, also concur in essential points. The latter make a brush of butt cuts of 6-inch okatkas, drawn from a "shake-up" instead of whole, trimmed, however, short enough to leave it but slightly penetrating. They make two grades, one with 452 tufts and the other 364, "Government size," tufts seven-eighths of an inch high, butt cuts only used in both; price about $15. The flags are used for lower grades of brushes. J. F. Herbert, of New York, makes a solid brush with 385 tufts, $\frac{13}{16}$ of an inch high, using, he says, only 2½ ounces of 5½-inch Siberian okatkas in each. The butts and flags are drawn in alternate rows, the last, or outside row, being of butt cuts. He admits that yellow Turkish and Russian bristles are frequently adulterated with "paint stubs" (bristles from worn-out paint brushes) by some manufacturers, and that the fraud is difficult to detect. Such material is of very inferior quality for horse-brushes, owing to the use of soda to remove the dried and indurated paint.

Miles Brothers, of New York, express the opinion that a penetrating horse-brush is better for cleaning, but not so durable; that the length of stock procured for horse-brushes and the number of cuts to be taken from it should depend upon the kind of stock and the character of the brush to be made. They recommend the "shake-up" for stock cut into two or more lengths. They say the height of the tufts should be determined by their size, proximity, and the stiffness of the stock; that in proportion as the bristles are weak the tufts should be short.

SELECTION OF STOCK.

Opinions expressed by various brush-makers and dealers in bristles differ widely as to the percentage of "shoe-hair" that ought to be found in suitable stock for horse-brushes, some putting it as low as 12 per cent. and others as high as 50 per cent., a difference difficult to reconcile. Such estimates cannot be based upon experience, for any stock yielding no more than 12 per cent. of stiff hair, with a No. 1 engine, can only make a brush too soft to be useful in the military service, while no stock among all the samples of "best okatkas" furnished to Watervliet arsenal during the past two years has been found stiff enough to yield 50 per cent., unless the specimens were taken wholly from the casings. The actual yield of "shoe-hair" from these okatka specimens has ranged from 9 to 35 per cent. Since okatkas are almost always cased, a yield of 35 per cent. from the center of the bundle would doubtless insure a good and economical stock for horse-brushes, unless the residue should be very soft, short, and woolly. Horse-brush stock should be selected, as a rule, long enough and stiff enough for two cuts at least, unless the flags can be disposed of economically, when only butt cuts are used. Long bristles are not necessarily proportionately stiff; therefore they should be selected with reference to both length and stiffness.

Brush makers and those accustomed to handling bristles are able to determine their quality by a casual examination without the aid of weighing scales, engines, the dragging process, and the size-stick. By parting the bundles at the root ends so as to expose the interior, the quality of that portion, in comparison with the casings, can be readily determined. If they have been "flagged up" (or "pricked up," as some say), to make the bundles appear to have less "taper," the roots of the short bristles will be seen scattered through the bundle sometimes as far up as the ligature. If the bundles, when not "flagged up," be parted at the soft ends and a portion bent over with the hand grasping the extremities of the flags, the short bristles below the hand not confined between longer ones will remain straight. In this way an experienced eye and an educated sense of touch are able to very accurately estimate the proportion of stout bristles in the bundle, and to determine the average quality of the whole.

The following hints relative to the selection of bristles may be of some service to such as have not given to the subject previous study or attention.

First, all things considered, 6 or 6½ inch okatka is the most suitable stock for Government use in the fabrication of horse-brushes. Secondly, they should not be "cased," that is, they should contain but a small percentage of short and weak hair, and no "wool." The interior of the bundles should furnish 30 to 35 per cent. of coarse hair, with a No. 1 engine, and a residue stiff enough for use with the better quality without greatly softening the brush. At least 90 per cent. of the whole bundle should be above 3—0, or 4½ inches.

Finally, care should be taken to select dry stock. Bristles stored in damp places absorb moisture, which adds considerably to their weight. Nine ounces of dry stock per 1,000 tufts of standard size and length is a liberal estimate. The unavoidable waste in cutting up such stock amounts to about 10 per cent. of the weight.

SIMPLE BRUSHES.

WHITEWASH BRUSHES.

The principal varieties of this class are whitewashers', calciminers', painters,' varnishers', grainers' and artists' tools.

Whitewash brushes are found in the market in great variety as to material, size, mode of manufacture, and price. As to material, the variations run through all the grades and mixtures of bristles, from the best white okatkas down to the poorest American stock mixed with tampico. The principal variations in size are in the length of the head, usually between 6½ and 9 inches, and in the length of the bristles, ranging from about 2½ inches to 7 inches. Stock for whitewash brushes, after being carefully combed, dragged, and mixed for the grade of brush wanted, is accurately weighed out in a brush-maker's scales; a beam-balance of the usual form, except that one scale-pan is replaced by a hook-shaped receptacle for the bristles. (Fig. 5, Plate XXVII.) If the brush is to have a casing, that portion is weighed out separately, and added to the stock designed for the center, in such a manner that when the brush is completed the casing shall be evenly distributed over the whole exterior, an operation requiring great dexterity in order to produce a satisfactory result. For a leather-bound brush the workman attaches one end of the leather band, with a tack, to the end of the head near the lower edge, and then spreads the butts of the bristles, with the casing outside, along the lower margin of the head, stretching the leather band over them and putting in an occasional tack, until the bristles have been distributed evenly around the head, all parallel to each other and perpendicular to the head. A straight-edge is applied to the butts to even them and push them all down flush with the edge of the leather band. When the arrangement is satisfactory, a sufficient number of nails are driven through the band and bristles to secure the whole firmly to the head. (Figs. 2, 4, 5, and 6, Plate XXXII, represent whitewash brushes of this kind.) A modification of this construction, patented by John L. Whiting & Son, is represented in Fig. 3, Plate XXXII. A wide saw-kerf is made in the lower side of the head, into which a piece of plate iron is introduced to clinch the nails upon. The following quotation is from the patentees' "Trade Price List":

> These brushes possess two entirely new features, both practically useful, which are applied to the regular leather-bound whitewash brushes. The open space in the block or head of the brushes serves as a temporary receptacle for the whitewash or other liquid, and therefore renders the brush less likely to leak or drip when being used; while, upon dipping the brush, or reversing its position, the liquid will readily run out. The other original feature adds greatly to the strength of the brush; the nails, being clinched on the inside, can never pull out or start. These brushes are in every respect first class, in addition to the above peculiarities.

Another method of construction is shown in Fig. 1, Plate XXXII. A metal band is substituted for leather, with one-third of its width embracing the head and two-thirds the bristles. A tenon on the lower side of the head, about one-third its thickness, projects a little below the band. The bristles are arranged in a layer of uniform thickness around the tenon, with the butts resting against a shoulder under the band. A row of nails through the lower edge of the band and the bristles into the tenon holds the bristles, while an upper row of nails through the band into the head secures the whole together. Stock for this brush is accurately weighed out as for the foregoing, including casing, if desired, but instead of being arranged under the band as in the preceding method, it is formed into the shape of the brush (only sufficiently thinner to allow for the thickness of the tenon) and moistened with a kind of sizing made of flaxseed, to facilitate handling by causing the bristles to adhere to each other. After the sizing has dried, the brush is clamped in a kind of wooden vise with broad jaws hollowed out to receive it. The end to be attached to the head, with about half the length of the brush, projects from the vise. The roots of the bristles are smeared with cement to nearly the depth covered by the band, when the brush is finished. The band is then passed over the brush and down to the vise. The bristles are parted through the middle with a long knife, and the tenon of the brush-head, also dipped in cement, is inserted. The band is finally pushed back to its place and securely nailed. In some factories the tenon is separate from the head, and is introduced as a wedge to which the band and the bristles are nailed before the head is attached. In others the tenon is replaced by a tongue glued and nailed into a groove in the head, but with the grain in the opposite direction to prevent splitting. The handles of whitewash brushes are usually detachable at will, being loosely inserted in holes bored in the head for the purpose. The following hint relative to the abuse of whitewash brushes may be of some value:

> Never put a brush in newly-slaked lime, as it will surely destroy the bristles. We have seen the best all-bristle brushes spoiled by being put into fresh-slaked lime, through carelessness or ignorance of the consumer, and then pronounced as being made of inferior stock or not all bristles.*

CALCIMINE BRUSHES.

Calcimine brushes differ from whitewash brushes in generally having a permanent handle continuous with the head, and in having wider limits of variation in size. The widths vary from about 3 inches to 6½ inches, the smaller ones being frequently used for wall-paint brushes. They are generally bound with brass instead of leather, and are more neatly finished in other respects. The methods of attachment to the handle are the same as in the metal-bound whitewash brush. The grain of the wood composing the handle is parallel to the bristles, but in wide brushes the portions each side of the handle are doweled and glued on with the grain running in the opposite direction to prevent splitting. Calcimine heads bored for handles like whitewash heads are made for such as prefer them. The stock required for these brushes is about the same in quality as that used for best whitewash brushes, and the cost for corresponding sizes is about the same. (Plate XXXIII.)

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* Miles Bro.s' illustrated Price List.

PAINT AND VARNISH BRUSHES.

> In no particular ought the painter or varnisher who wishes to insure superiority in the execution of his work to be more circumspect than in the choice of his brushes and pencils.
>
> Brushes are either round or flat, and are of various sizes. The round ones range from a quarter of an inch to 2½ inches in diameter. For some particular purposes they even exceed this latter size. The larger ones are made use of in laying on the first coat of paint, or priming, as it is called, and in painting over large surfaces which require considerable quantities of color. The smaller brushes are for parts to which, from their size or situation, the large ones cannot be applied.
>
> Brushes of a flat form are usually termed varnishing brushes, being chiefly used for that purpose; but they are likewise employed in drawing lines, veining, and imitations of variegated woods.

A correspondent of the Mechanics' Magazine makes an objection to the use of round brushes which must be allowed to have considerable weight. Being round, he says:

> They are by no means well adapted, in that shape, for laying on a flat surface; the consequence is that painters invariably use their brushes but one way, for the very purpose of wearing them flat, which goes to prove the necessity of an alteration in their shape. * * * Brushes are almost always made of hogs' bristles. Sometimes they are of badgers' or goats' hair, especially when required for varnishing fine work with a thin varnish. In choosing them, observe, in the first place, that the hairs are strong, and next, that they are close together, and fast bound with the threads that lie round them in the stocks. If the hairs are weak the color will never lie in a good body; if they are not close together, they will spread and divide unequally when used, and consequently cannot work well. But the worst fault of all is in their not being fast bound in the stocks; for, in that case some will come out while you are working, and the appearance of the work will be strangely disfigured by loose hairs being seen buried in the coloring when dry. Even when as tightly bound together as possible the hairs often get loose, from the practice so common with painters, of keeping their brushes in water when out of use, by which the strings that bind them, though usually glued over, soon become rotten. To prevent brushes from being damaged in this way, get them bound in the usual way, but not glued over, and then work in rosin and grease, which will resist the water and keep the brush for a long time tight and sound. When, by long use, the hairs of a good brush begin to work loose, drive a few thin wedges of wood inside the thread with which they are bound round, and this will render the whole fast again.*

The larger sizes of paint and varnish brushes, to be of superior quality, should be composed of long, stiff, well-dressed bristles (preferably white), with soft, clean flags and due proportion of "casings," "draggings," and "taper." The casings (which are also dragged sizes, and generally white, while the interior is of the gray, yellow or black) should be of nearly the same length for the same brush, and should be carefully arranged to form an envelope of uniform thickness around it. The natural curve or bend of the hair should be toward the center to prevent excessive splay of the brush when in use. The draggings and taper which form the interior must be skillfully proportioned and thoroughly mixed so that the brush shall have a sufficient and uniform taper without "breaks," and, when laid on the work, shall present as near a "chisel-edge" as possible.

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*"'The Painters,' Gilders', an Varnishers' Companion."

PREPARATION OF STOCK, AND MANUFACTURE OF PAINT AND VARNISH BRUSHES.

The preparation of paint-stock from either raw or dressed material does not differ from the preparation of stock for other brushes, except that greater care is exercised to have it clean and well assorted as to size, color, and quality, and to have the white well bleached. In large factories paint-stock is usually prepared by specialists (combers), who are employed exclusively upon it. All the various assortments are stored away separately in boxes, ready for the hands of other specialists whose business it is to compound and mix them in due proportions to produce brushes of certain grades and values. Under the direction of the foreman, specified quantities of stock, in the different sizes, colors, and qualities known by experience to be necessary to make the kind of brush desired, are taken from the store and piled in long tiers on the bench, each tier being built up of the same assortments in layers of equal and uniform thicknesses, so that when divided into vertical sections each section will be composed of like proportions of all the assortments. Specimens of this stock, after being thoroughly combed and mixed, are submitted to the foreman for examination. If found satisfactory it is *all* combed, mixed, and accurately weighed out into parcels, each sufficient for a brush, less the casing. Flat paint brushes are cased and laid up the same as calcimine brushes. The sizes are smaller, however, ranging from 3 inches to 5 inches wide. Many are not cased; some have "chiseled edges" (a characteristic to be presently explained), and some of the smaller varieties, like coach-painters' color-brushes, and camel's-hair varnishing and copying brushes, are not directly attached to the handle, but inserted in one end of a flat tin ferrule with the handle in the other. Rivets or clinch-nails through both brush and handle fasten the whole together (Plates XXXIV, XXXVII, XXXVIII). For oval and round brushes the casing is accurately weighed out and spread on the bench in a layer of uniform thickness and just long enough to envelop the brush without overlapping. The mixed stock, previously weighed out, is spread upon it, and the whole deftly rolled together so as to leave the casing on the outside. Each parcel is finally tied with twine, and the root-end, dipped in cement, is inserted into a ring of proper diameter, generally made of coiled wire with the helices soldered together. The handle, which is usually in the form of a slender cone, is then driven through the axis of the brush point foremost like a wedge. It is accurately centered among the flags, and driven home with a heavy hammer and a graduated drift. The drift is necessary to avoid breaking the bristles with the hammer, and to indicate the exact depth to which the handle is required to be buried in the brush. The end of the handle must not project below the lower margin of the ring; otherwise the brush will have too much spread and a hollow center. While driving the handle the brush rests, flags uppermost, upon an iron plate which lies on the bench, and has a hole in it large enough to permit the handle to pass through. Sometimes, to make the most of short bristles, the brush is not inserted to the full width of the ring, one-half or more of the latter being frequently filled around the handle with an annular block of wood. The wooden block may be inserted into the ring at the same time with the brush and the handle driven through both, or the handle may be driven with the brush resting on a raised disk on the bench-plate filling the ring to the depth it is designed subsequently to plug it with wood.

Extreme accuracy is necessary in assorting and weighing stock for brushes of this kind, in order that the driving of the handle may neither burst the rings nor leave the bristles so loose as to be liable to fall out with a slight shrinkage of the handle. The same nicety is not necessary in fitting flat brushes into the binding rings, as a little excess of stock merely reduces the manufacturer's profit, and a deficiency only depreciates the brush to the extent of the value of the missing material.

Formerly twine was used almost exclusively to bind round and oval brushes to the handles, but latterly it has been almost entirely superseded by wire and rings of solid metal, except for some small brushes like sash-tools. Solid brass rings are used with the lower edge crimped in to make the brush more compact. (Fig. 4, Plate XXXV.)

Paint brushes made by the process just described are termed ***open-center brushes***, from having a conical hollow below the handle, as seen in Figs. 5 and 8, Plate XXXV, which represent axial sections of open-center brushes made as described, except that there are pins on the lower side of the annular wooden plug which penetrate the brush nearly to the lower margin of the ring. This latter is a feature patented by John L. Whiting & Son, and is applied by them to the manufacture of solid-center brushes, two of which are shown in section in Figs. 1 and 9, Plate XXXV, and to modifications of the open-center varieties. (Figs. 3 and 7, Plate XXXV.) The following is what the patentees claim for this peculiar method of construction:

> The original full-center patent has several advantages over the old style of manufacture, and especially over brushes having butts or disks of wood or other substances inserted within the ferrule, but having no mechanical connection with the bristles:
>
> 1. It is much stronger, as much force being used in driving the handle as is required in the old method. A very much extended surface of the handle is brought in contact with the bristles. The butts of the bristles are saturated with the best of brushmakers' cement, so that the holding power of both the pressure and cement is proportionately increased. Practically, the bristles and handles are grown together.
>
> 2. The hollow cone in the center of the brush, a necessity of the old method of manufacture, being entirely obviated, the brush cannot "swallow-tail" or wear out in the center, but wears up evenly until it is worn out.
>
> 3. It will be noticed that the bristles are evenly distributed throughout the brush, and not compressed into a solid ring or shell between the handle and ferrule around a reservoir for paint in the center of the brush.
>
> Reservoirs have never been a success in other kinds of brushes, and have only been tolerated in paint brushes heretofore from necessity. As a consequence of this peculiarity the brush is a little more mellow than other kinds of brushes, allowing a little more elasticity or spring near the ferrule, and in consequence will wear up shorter before being laid aside as a "stub."

Concerning the modified construction shown in Fig. 3, Plate XXXV, they say:

> This brush is a modification of the original full-center brush, and by some considered an improvement. The plug, or section of the old-style paint-handle, driven into the center, acts on the principle of the wedge and in the opposite direction from the wedges of the handle, and thus holds the handle and bristles within the ferrule, if possible, more securely. At the same time, the central space being very small, the brush retains all, or nearly all, the advantages of the full-center brush.

Referring to the sash-tool represented in Fig. 8, Plate XXXVI, they say:

> All the merits of the full-center patent are embodied in this brush. Without exception, it has given better satisfaction than any other sash-tool heretofore manufactured.

Sash-tools are usually made with solid centers, and being small, can be produced by various means not practicable with larger brushes. A good quality is made by a process (not represented in the accompanying illustrations) similar to that already described for open-center paint brushes, the difference being that the wire ring is conical and the handle is driven butt end foremost. The small end of the ring embraces the brush and the large end the handle. The brush-tuft tightly bound with thread and dipped in cement is inserted, flags foremost, into the ring by way of the larger end, and the handle is driven in after it. A small cone formed on the end of the handle penetrates the brush to the lower margin of the ring, securely wedging in the bristles without a tendency to spread them below. Very satisfactory sash-tools are also made by inserting a tuft of bristles, bound with thread and smeared with cement, into a hole, bored in the end of the handle, of such a diameter as to leave only a thin shell of wood. This shell is divided into six or eight equal parts by saw-cuts in the direction of the axis, to permit a little expansion, an easy insertion of a close-fitting tuft, and, finally, contraction under pressure of the binding twine.

A fourth method is to cut away the central portion of the butt end of the handle, leaving only two prongs projecting from opposite sides, like a fork, between which the bristles are bound with twine as before (see Plate XXXVI). Good sash-tools are made by either of the four processes described; though the first two are thought by some rather superior to the others in point of durability, and are preferred if equal in other respects. Selection is generally made, however, with reference to the quality of the bristles rather than the method of their attachment to the handle. The best sash-tools are not cased but made solid of French stock; a lower grade is made of white American stock cased with French; next a gray American center with French casings; and, finally, all American stock.

Brushes designed for varnishing differ from color brushes generally in being shorter and softer, and the flat varieties in being much smaller. The processes of fabrication are the same, except that small flat brushes for use on fine work with a thin varnish are attached to the handles in a somewhat different manner, already explained. These last are usually composed of some softer hair than bristles, such as the hair of the camel, goat, sable, badger, and fitch (skunk's hair), &c. (Plates XXXIV, XXXV, XXXVI, XXXVII.)

CHISELED EDGES.

To obviate the objection to round brushes, made by a correspondent of the Mechanic's Magazine, already quoted, and to better adapt them "for laying on a flat surface," they have lately been made with what is called a "chiseled edge," that is, the flags of the bristles are so disposed as to give to the soft end of the brush the form of a blunt wedge. This improvement is applied to both paint and varnish brushes, and to the *flat* varieties as well as to the *round* and *oval*. The proper arrangement of the flags to form the "chiseled" edge is effected in a box having an interior shape like that to be imparted to the exterior of the brush. It is open at the top, and the bottom is closed by two plane surfaces equally inclined to the axis, and intersecting in a line perpendicular to it. It is large enough in diameter to permit the easy introduction of all the bristles for the brush, and in depth something less than their length. The bristles are first prepared without "taper," and accurately weighed as for other forms of brushes, then combed and introduced, flags downward, into the box. The slopes of the bottom are coated with fine sand and glue, so that the flags do not slip down toward the center, but remain in a vertical position. By gently jarring the box all the bristles sink until they come in contact with the sanded surfaces, so that finally the soft end of the bundle of bristles assumes the exact shape of the bottom of the box. The root end is then firmly bound with twine before removal from the box. The roots, made uneven by the process, are trimmed off with shears similar to those used for cutting up stock. The brush is then finished by one of the processes described for either solid or open center brushes. The chisel shape is also produced by a process nearly the reverse of that just described. The tuft is weighed out as before and securely tied by the middle. The chisel shape is first given to the *root end* by clipping with shears, and is then transferred to the flag end by loosening the ligature and "butting down" the shortened hairs.*

STENCIL BRUSHES.

The best stencil brushes are square at the end, short, solid, and moderately stiff. They are usually made of bristles with the flags cut off. Ordinary paint brushes are unsuitable for the purpose on account of their length and pliability, and the consequent tendency of the hairs to bend and work the color under the edges of the stencil, wherever it does not lie closely upon the work, leaving the painted figures with jagged margins. Stencil brushes are mounted either on long handles like paint brushes (Fig. 10, Plate XXXV), or on short handles like barbers' shaving brushes (Figs. 2 and 3, Plate XXXIX).

GRAINERS' AND GILDERS' BRUSHES.

These present no new feature in construction or material sufficiently characteristic to claim especial description, excepting such as may be classed as pencils. Those in most common use are represented in Plates XXXVIII, XXXIX, and XL.

PENCILS, ARTISTS' AND FRESCO BRUSHES.

Pencils differ from brushes in the smallness of their size, and in being manufactured of a much finer and softer hair. In some cases the hair of the marten, or of children, and even swans' down, are used for them; but these are generally confined to pencils intended for artists, the mechanical painter being rarely ever engaged in work of such a delicate nature as to require them. The smallest are fitted into the barrels of quills, the larger sort into tin cases, both placed at the end of sticks; some, of a very large size, are fastened into stocks in the same manner as brushes. In choosing pencils a very simple trial will prove whether they are fit for your purpose. You have only to put them into your mouth, and after wetting them a little, draw them out between your tongue and upper lip; then, if they present a sharp point, and the hairs come out full next to the case and without separating, the pencils are good; if the hairs show ragged or are thin at the opposite end to the point, they cannot be depended upon. The sharpness of the point is of particular consequence in small pencils. The same attention must be paid to the hairs being fast bound in the stocks or cases, as directed in the choice of brushes.

With regard to the stick or stock attached to the pencil, it ought never to be less than eight inches; and, indeed, the greater the length, provided the workman can handle it with freedom and certainty, the better; for it is as impossible for a painter to have a good command of his pencil as a writer of his pen if he held it too near the point.† * * *

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*These are the common methods employed by most manufacturers for making chiseled edges. If other means of effecting the same object are known they are guarded as secrets by their discoverers.

† Painters', Gilders', and Varnishers' Companion.

Hair pencils or brushes for painting.—Two sorts are made: those with coarse hair, as that of the swine, the wild boar, the dog, &c., which are attached usually to short wooden rods as handles—these are commonly called *brushes*—and "hair pencils," properly so called, which are composed of very fine hairs, as of the minever, the marten, the badger, the polecat, &c. These are mounted in a quill when they are small or of moderate size, but when larger than a quill they are mounted in white iron tubes.

The most essential quality of a good pencil is to form a fine point, so that all the hairs, without exception, may be united when they are moistened by laying them upon the tongue or drawing them through the lips. When hairs present the form of an elongated cone in a pencil, their point only can be used. The whole difficulty consists, after the hairs are cleansed, in arranging them together so that all their points may lie in the same horizontal plane. We must wash the tails of the animals whose hairs are to be used by scouring them in a solution of alum till they be quite free from grease, and then steeping them for twenty-four hours in lukewarm water. We next squeeze out the water, by pressing them strongly from the root to the tip, in order to lay the hairs as smooth as possible. They are to be dried with pressure in linen cloths, combed in the longitudinal direction with a very fine-toothed comb, and finally wrapped up in fine linen and dried. When perfectly dried, the hairs are seized with pincers, cut across close to the skin, and arranged in separate heaps, according to their respective lengths. Each of these little heaps is placed separately, one after the other, in small tin pans with flat bottoms, with the tips of the hair upwards. On striking the bottom of the pan slightly upon the table the hairs get arranged parallel to each other, and their delicate points rise more or less according to their lengths. The larger ones are to be picked out and made into so many separate parcels, whereby each parcel may be composed of equally long hairs. The perfection of the pencil depends upon this quality, the tapering point being produced simply by the attenuation of the tips. A pinch of one of these parcels is then taken, of a thickness corresponding to the intended size of the pencil; it is set in a little tin pan, with its tips undermost, and is shaken by striking the pan on the table as before. The root ends of the hairs being tied by the fisherman's or seaman's knot with a fine thread, it is taken out of the pan and then hooped with stronger thread or twine, the knots being drawn very tight by means of the little sticks. The distance from the tips at which these ligatures are placed is, of course, relative to the nature of the hair and the desired length of the pencil. The base of the pencil must be trimmed flat with a pair of scissors. Nothing now remains to be done but to mount the pencils in quill or tin-plate tubes as above described. The quills are those of swans, geese, ducks, lapwings, pigeons, or larks, according to the size of the pencils. They are steeped during twenty-four hours in water, to swell and soften them, and to prevent the chance of their splitting when the hair brush is pressed into them. The brush of hair is introduced by its tips into the large end of the cut quill, having previously drawn them to a point with the lips, when it is pushed forwards with a wire of the same diameter till it comes out at the other and narrower end of the quill. The smaller the pencil the finer the hairs ought to be. In this respect the manufacture requires much delicacy of tact and experience. It is said there are only four first-rate hands amongst all the dexterous pencil-makers of Paris, and that these are principally women.*

CONCLUSION.

It may be superfluous to add that this report was not intended to do more than throw a little light on the subject of brush-making and the various industrial and commercial interests involved in it. It would have been impracticable, even if desirable, to make it a complete brush-maker's manual. The accomplishment of such an undertaking would require long familiarity with the business in all its details, or persistent inquiry among craftsmen engaged in it; the one only possible to a practical brush-maker, and the other only successful to one able to offer an equivalent for what he seeks. Brush-makers naturally do not relish being interviewed on the subject of their business, especially when the interview does not point unmistakably to an advancement of their interests, and the inquirer is often as likely to be altogether misled as to get any reliable information upon matters affected by competition. There are few manufacturing industries in which competition is sharper; and, it may be said, few in which resort is had to so many cunning expedients to reduce the cost of manufactures without depreciating them in the market. It should be remembered that all standard types of brushes are determined by the demand, and that all manufacturers are compelled to produce substantially the same varieties, so that honest competition is mainly limited to quality of workmanship and of materials. Many types are, however, slightly modified in the details of construction, by makers who frequently control by patent some peculiarity which, perhaps, increases the demand, lessens the cost, or operates in some way to give an advantage in trade. The patented features at least give a monopoly of manufacture, and furnish the patentee a basis for pretended superiority of his brushes, which often serves his purpose as well as intrinsic excellence.

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* Ure's Dictionary of Arts, Manufactures, and Mines.

The more mischievous modifications of standard types are those which are not so apparent, and which are resorted to for purposes of deception. Concerning these "tricks of the trade" little could be learned. Brush-makers who practice them cannot be expected to be communicative on the subject. Interested visitors are either wholly excluded from their workshops, or are only admitted to certain departments, and at times when an ostentatious display of honest work can be made, so that it is only when exposed by a rival manufacturer or a defrauded purchaser that their counterfeits become known and can be avoided. In this important particular this report is much less full than could be desired; yet, through the politeness of a few prominent manufacturers, and limited opportunities for observation among dealers and users, some information has been obtained, for example, that the stamp "warranted all bristles" on the back of a horse-brush is no guaranty that it does not contain a large percentage of tampico; that the mark "warranted best quality of okatka" is no sure indication that the brush is not made of "paint-stubs" or of wornout whitewash or calcimine brushes, and, perhaps, adulterated with vegetable fiber; that although paint brushes may be "warranted full standard weight," there is reasonable ground for suspicion that they may be loaded with lead, either in the form of a plug in that portion of the handle buried in the brush, or of thin strips among the bristles under the ferrule; that notwithstanding paint brushes may be of standard length, it is still possible that they are composed of short stock made to appear long by insufficient insertion into the ferrule to make a secure attachment to the handle; that whatever the marks on a brush, and whatever its advertised qualities, it is (unless recognized as the product of a well-known and reliable manufacturer) likely to prove inferior to what is claimed for it; and likely to contain all the cheap material that can be worked into it without danger of detection. In fact, almost all the cheaper varieties of horse-brushes in the market are either composed of inferior domestic bristles, "paint-stubs," or some mixture of fiber and hair, such as are shown in Plate XII; even those sold at high prices are often found to be only spurious imitations.

Under the contract system of procuring supplies for the military service some imposition is sure to be encountered, and cannot be guarded against, even in the selection of samples, without constant vigilance and the closest scrutiny by experienced inspectors. The chances of securing brushes of standard excellence are not much improved when the Government supplies all materials. "Thrifty" contractors may still "economize" government stock and eke it out with their own baser materials, whether the compensation for their work be high or low. Greed of gain seems as likely to seek to swell a profit already large as to create a profit where little if any is honestly possible. Experience at this arsenal points to this conclusion. As much as one dollar each for labor only has been demanded for making horse-brushes (a price considered extortionate, and believed to be incompatible with honest purposes), while at another time another manufacturer proposed to do the same work for 26 cents, or a price so low as to barely cover the cost of the various operations at the usual prices paid for piece-work, and at which little if any profit could be made except by adulteration of the stock or by inferior workmanship.

The obvious deduction from these facts is that brushes for the military service should be manufactured in the Government workshops and under the direct supervision of some of its officers. Only skillful workmen should be employed, and great care exercised in the selection of bristles. By observing these precautions the manufacture of horse-brushes has already been successfully undertaken at Watervliet Arsenal, and can no doubt be continued with great advantage to the Government and to the military service, particularly if the appropriations for the work and the orders for fabrication can be so arranged as to warrant the promise of constant employment to the few skilled workmen who are necessary, but who cannot otherwise be easily obtained except by payment of exorbitant wages. Of course the economy of this method of supplying brushes will be affected by the number required to be fabricated.

Brushes, like almost every other manufactured article, can be produced in *large* much cheaper than in *small* quantities. To gain, therefore, the greatest possible advantage from the enterprise, all brushes for every department of the military service should be made at the same establishment, and should include paint, varnish, whitewash, calcimine, scrubbing, molders, bench and stencil brushes, sash-tools, pencils, &c. Extending the manufacture to embrace other varieties would not, however, provide additional work for men usually employed on horse-brushes. Most of the operations of paint-brush-making are specialties, and the same number of men would be required for this branch of the business as though no horse-brushes were made.

The advantages to be gained from the enlarged scope of the project would be greater economy of manufacture, and improvement in the quality of all the products. The stock would be all consumed without waste, and no brush would contain stock not entirely suitable for it. The soft hair, always found among okatkas, would not be worked into horse-brushes, increasing their cost without adding much to their value, but would be separated from horse-brush stock and turned to more profitable account in the manufacture of other kinds of brushes, for which it is better adapted.

Finally, the Government should import its own bristles, or purchase only bonded or debentured stock, and so save to the military appropriations the 15 cents per pound duty that would otherwise have to be added to the cost of fabrication.

The names of most manufacturers, dealers, importers, &c., who have in one way or another contributed to the matter of the foregoing report, have been mentioned therein and their services duly recognized. Besides these the name of Mr. Henry Kroehl, an importer of New York, should be mentioned with especial acknowledgments. To his large experience and courtesy the writer is indebted for much information concerning the traffic in foreign bristles.

A. L. VARNEY,
Captain of Ordnance.

Fig. 1.

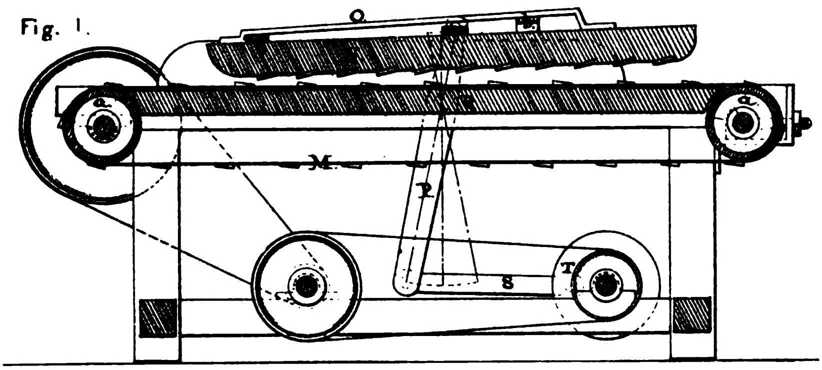
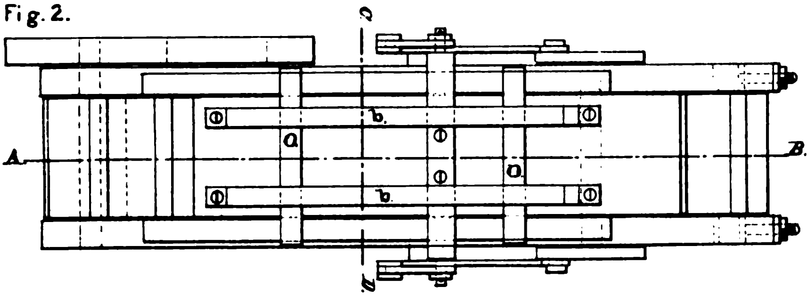


Fig. 2.



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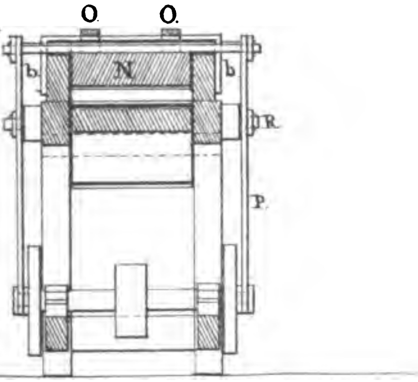


MACHINE FOR CLEANING AND SEPARATING BRISTLES.

Fig. 1

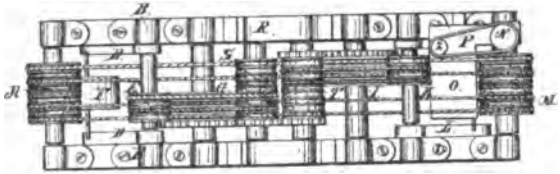


Fig. 2

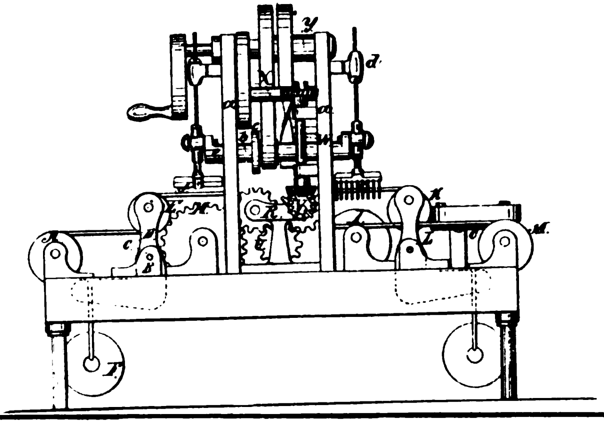


Fig. 3

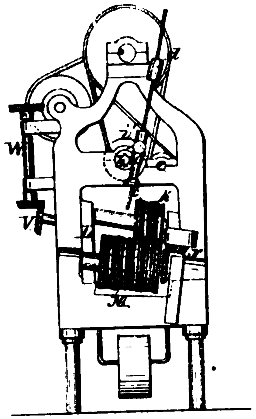


Fig. 4

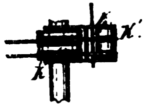
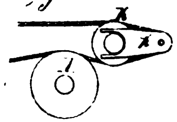


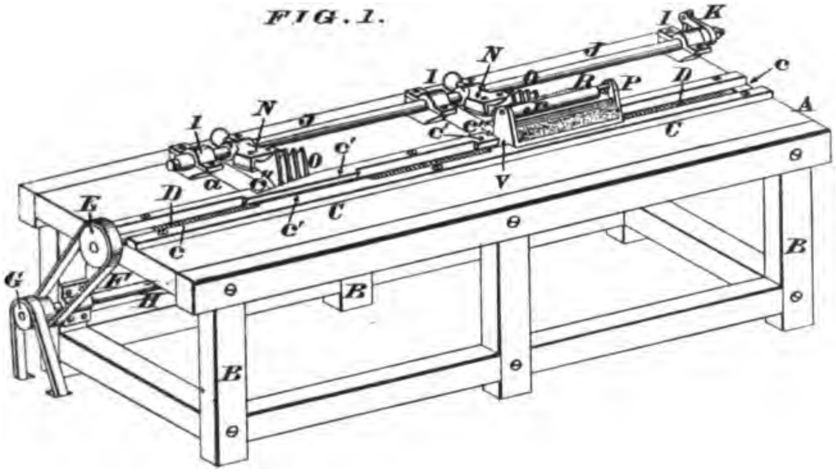
Fig. 5



MACHINE FOR COMBING BRISTLES.

PLATE III

FIG. 1.



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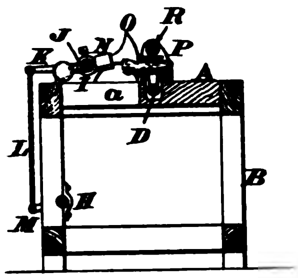


FIG. 3.

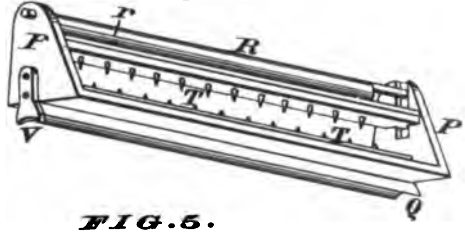


FIG. 5.

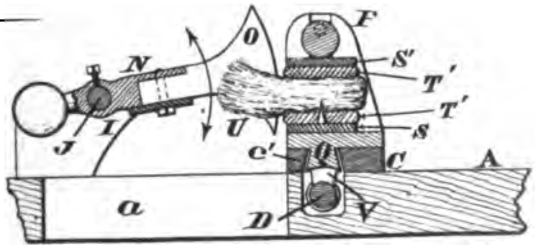
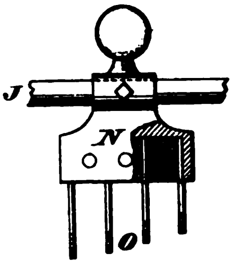
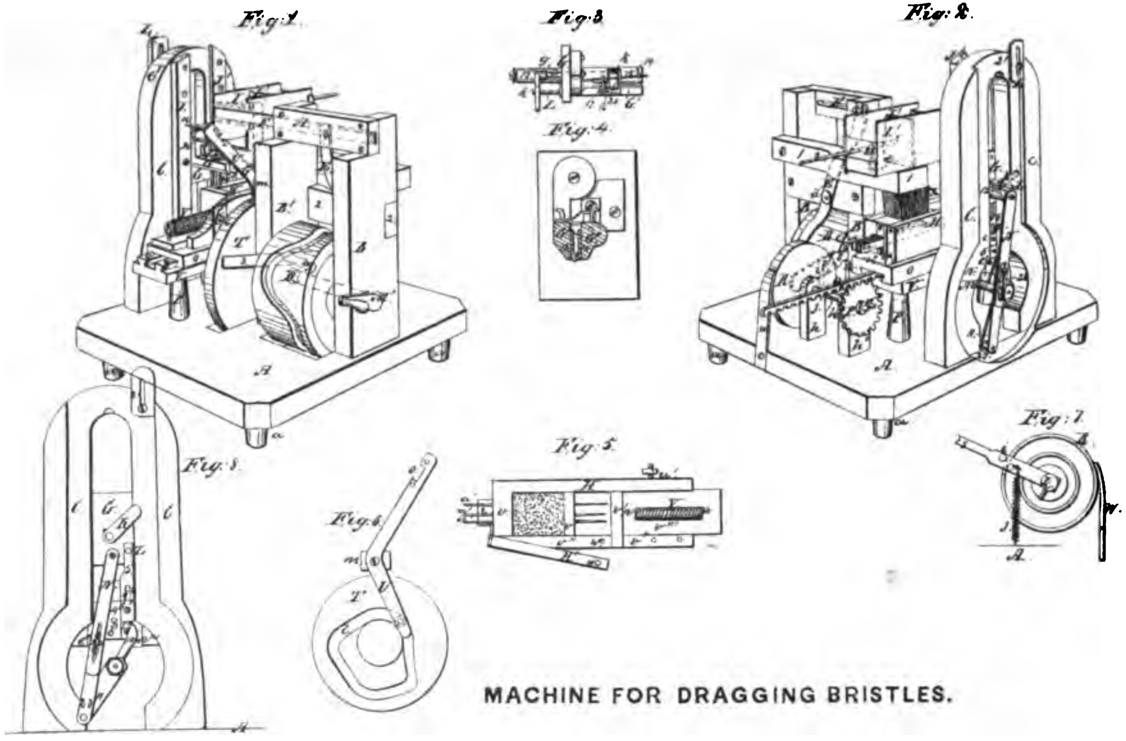


FIG. 4.



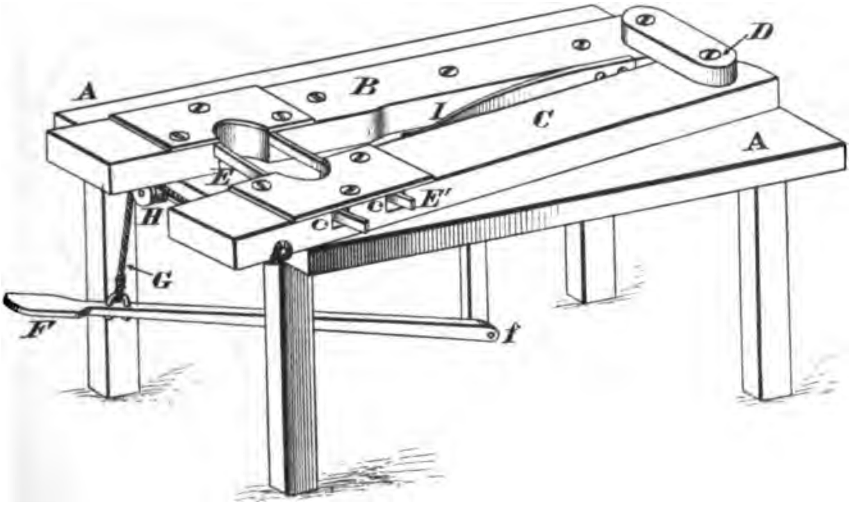
Machine for Combing Dry Bristles.



MACHINE FOR DRAGGING BRISTLES.

PLATE V

FIG. 1.



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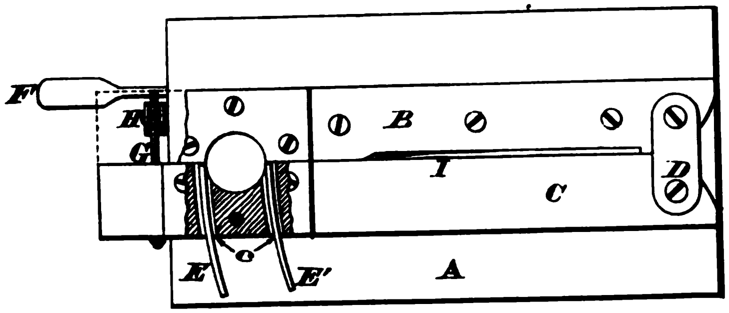
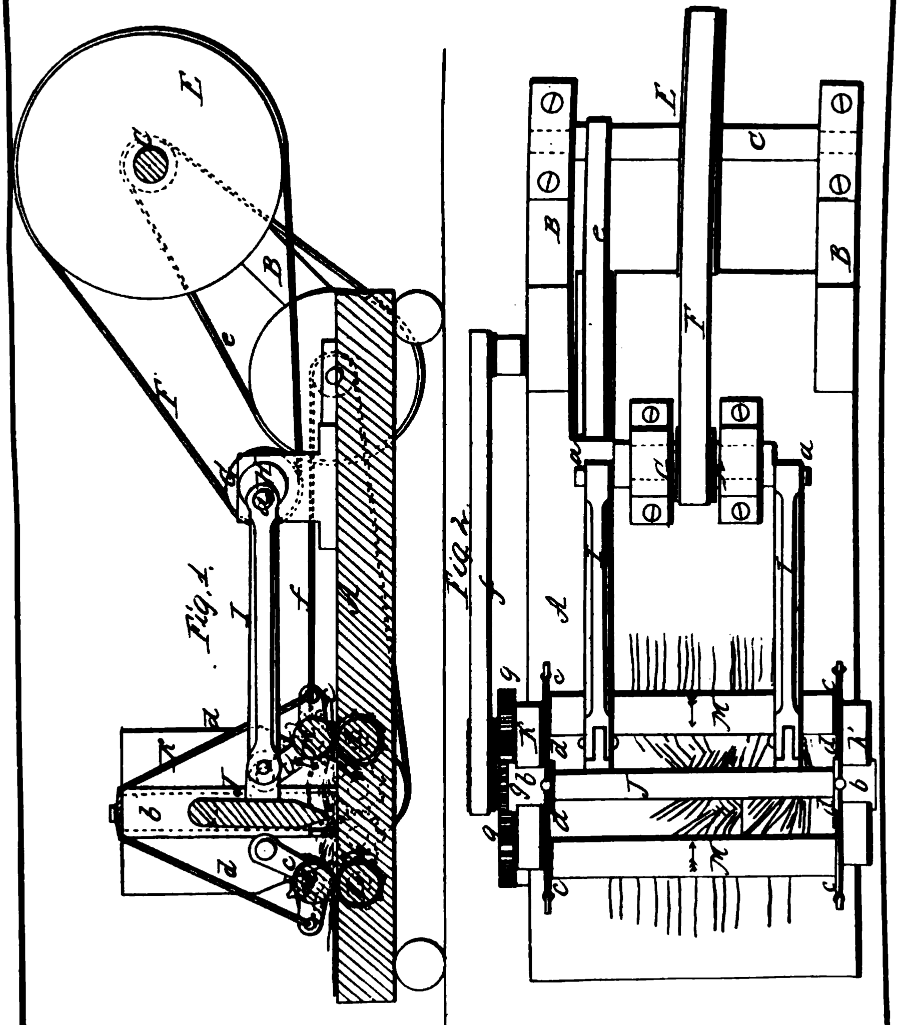


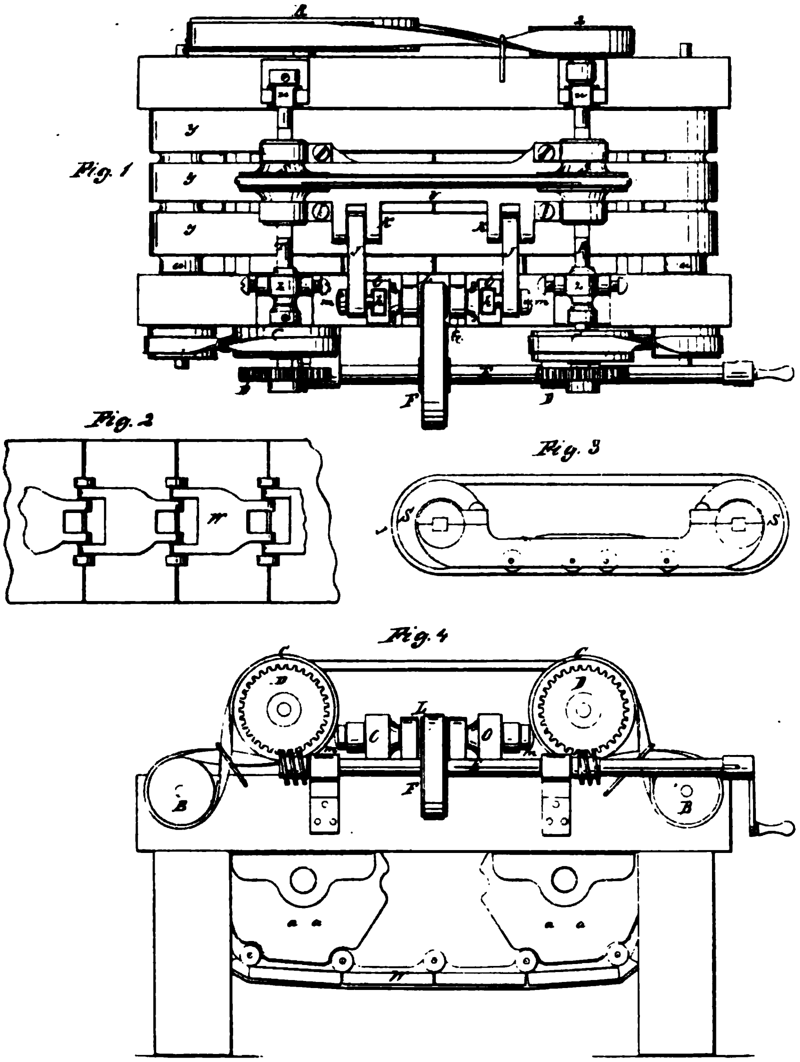
BRISTLE-BUNDLING MACHINE

PLATE VI

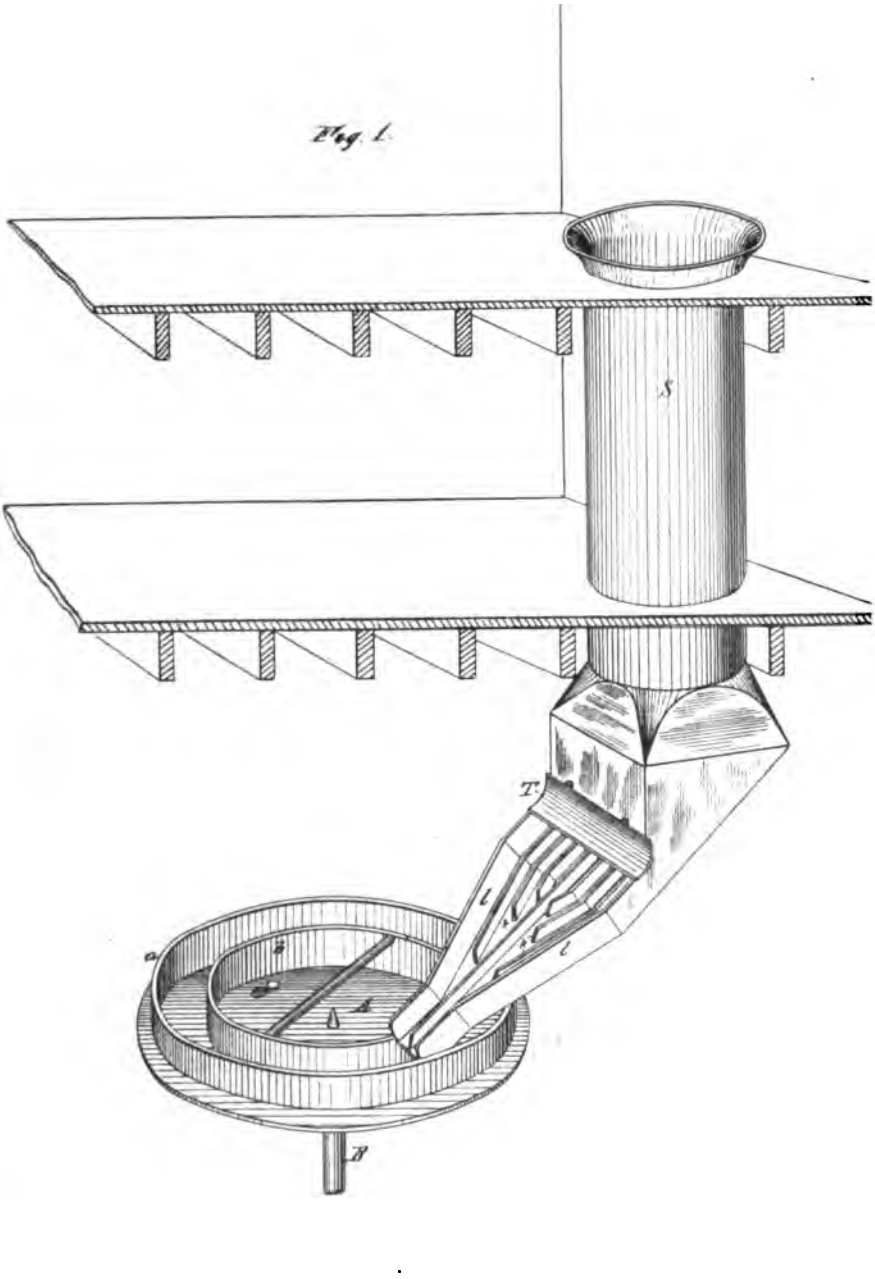


MACHINE FOR ARRANGING BRISTLES.

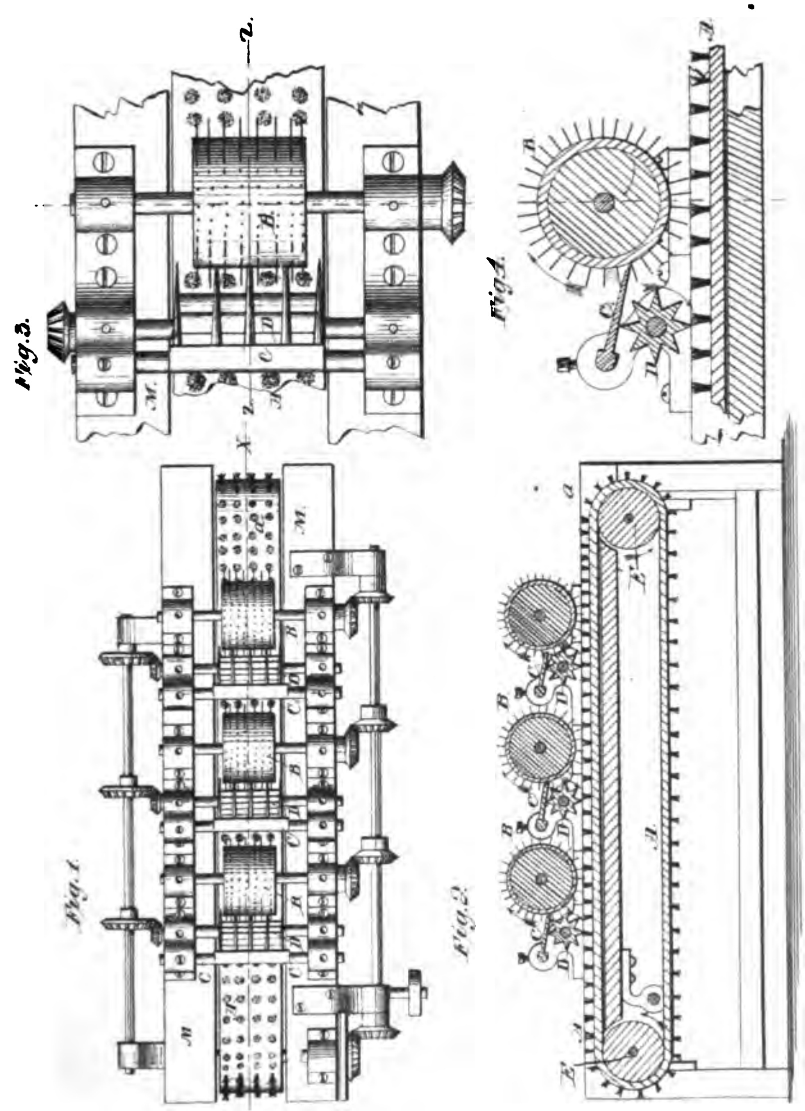
PLATE VI



MACHINE FOR SEPARATING BRISTLES.

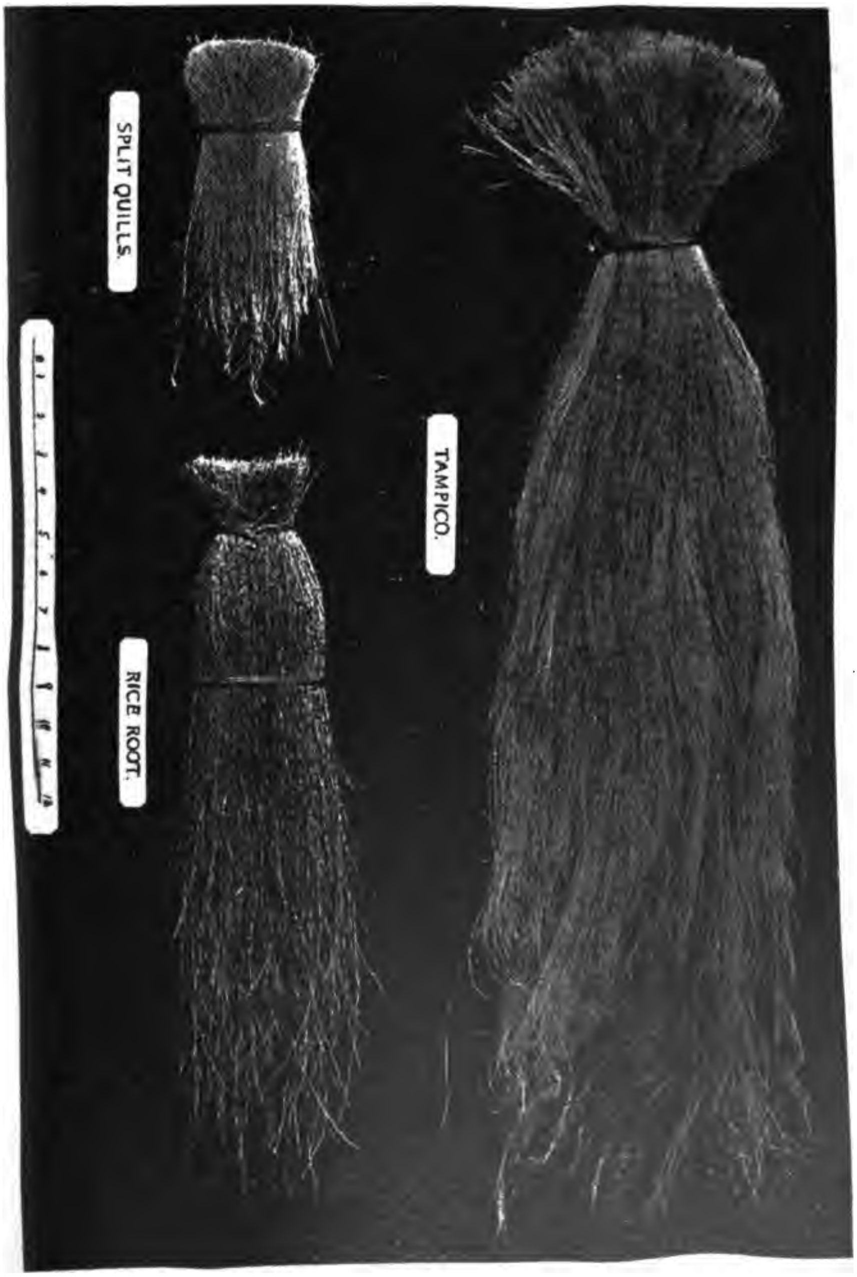


Method of and Machinery for Arranging Bristles.



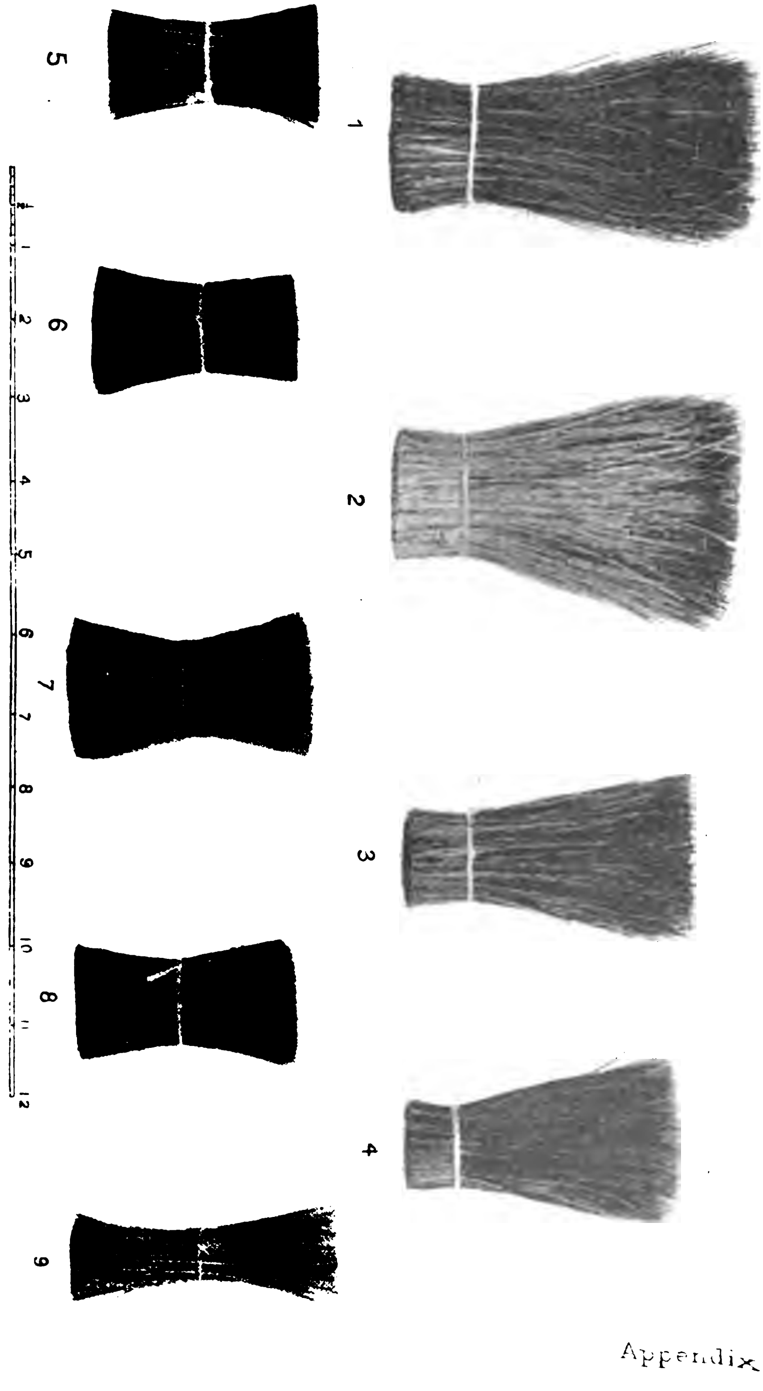
BRISTLE-MIXER

PLATE XI



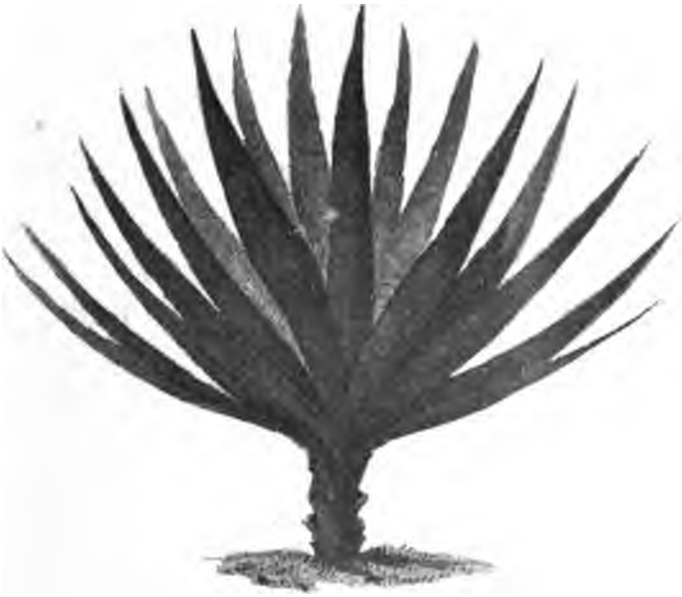
Appendix 21 1883.

PLATE XII



Appendix 21 1883

PLATE XIII

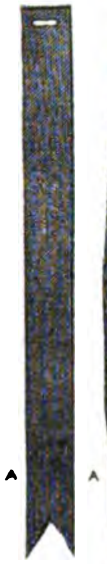


AGAVE SISILANA
(YASHQUI)

Appendix 21 1883

The Heliotype Printing Co Boston

PLATE XVI



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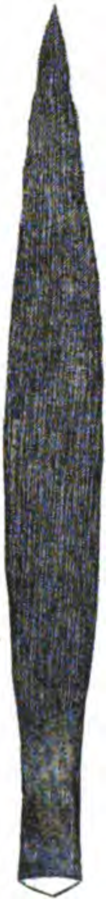

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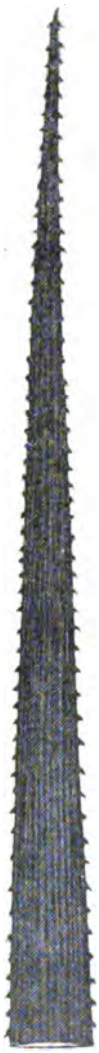

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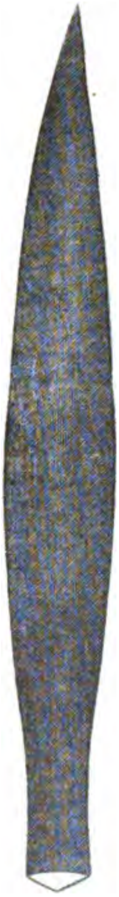

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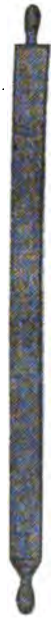

Fig 3.

Appendix

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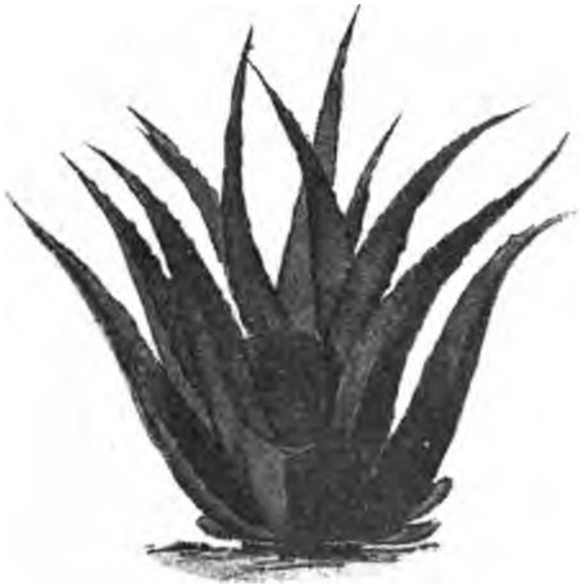
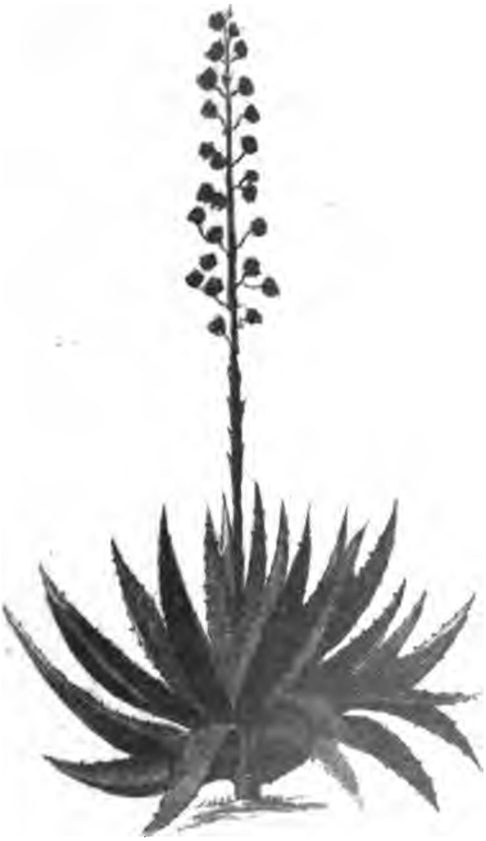
PLATE XV



AGAVE MEXICANA

Appendix 21 1983

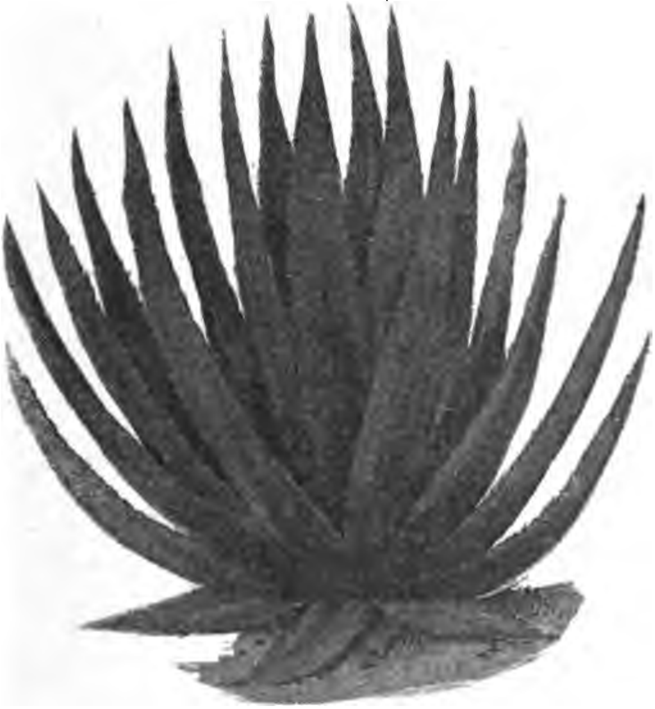


AGAVE AMERICANA
(CENTURY PLANT)

Appendix 21 1883.

The Heliotype Printing Co. Boston

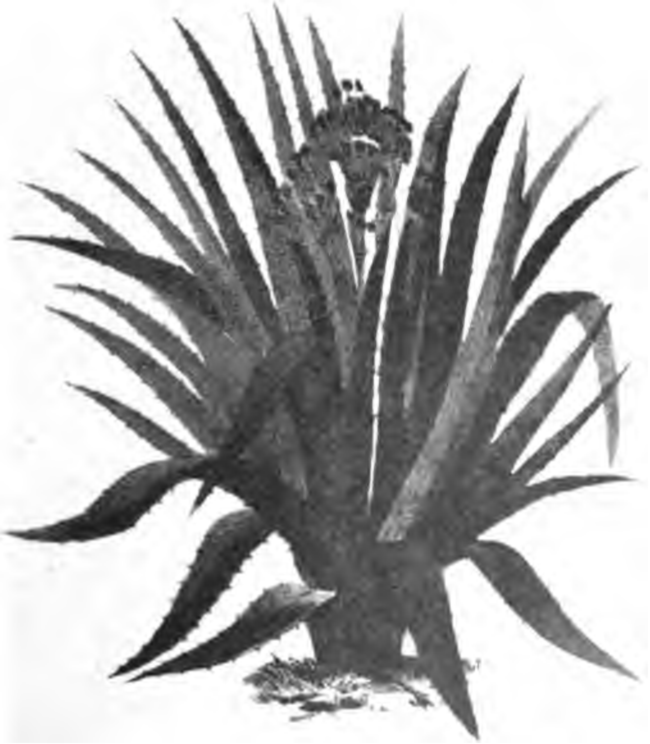
PLATE XVII



AGAVE VIRGINICA

Appendix 21 1883.

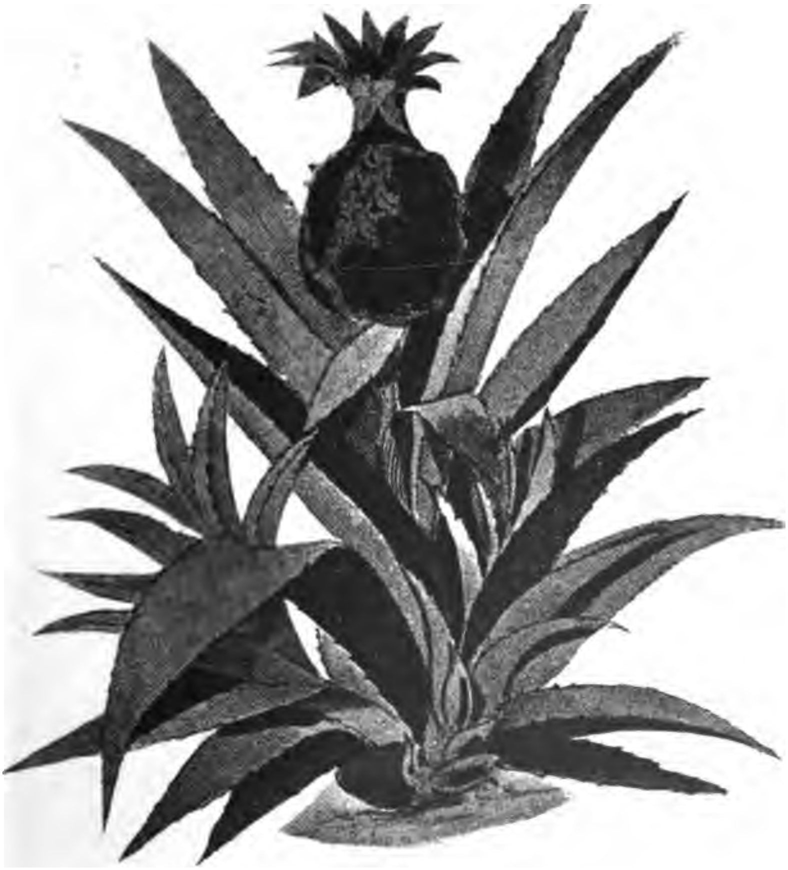
PLATE XVIII.



BROMELIA SYLVESTRIS OR PENGUIN
(WILD PINE APPLE)

Appendix 21 1883

The Heliotype Printing Co. Boston



BROMELIA ANANAS
(PINE APPLE.)

Appendix 21 1883.

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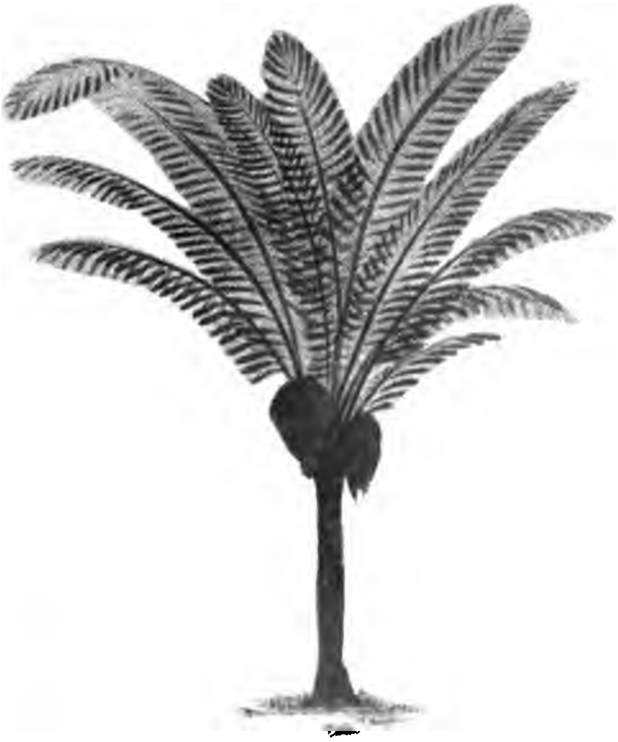
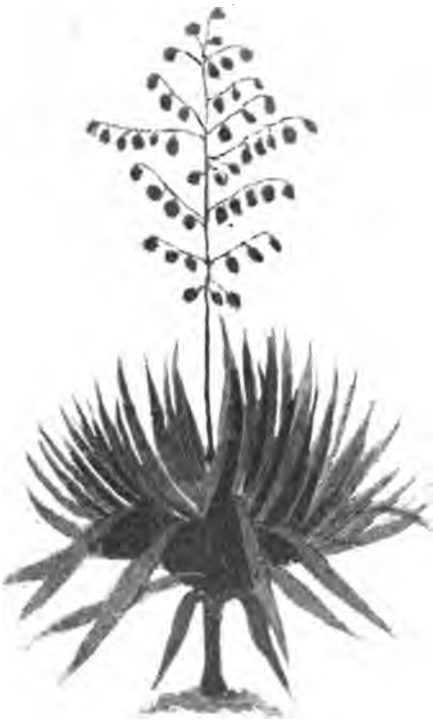


ARENGA SACCHARIFERA

Appendix 21 1883.

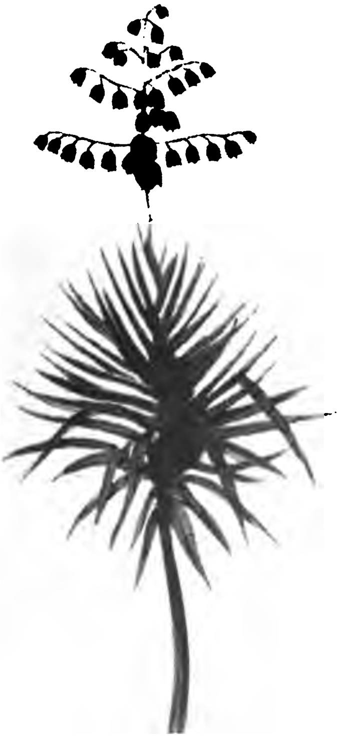
The Heliotype Printing Co. Boston



YUCCA GLORIOSA
(SPANISH BAYONET)

Appendix

The Heliotype Printing Co Boston



YUCCA ALOIFOLIA.

Appendix 21 1883.

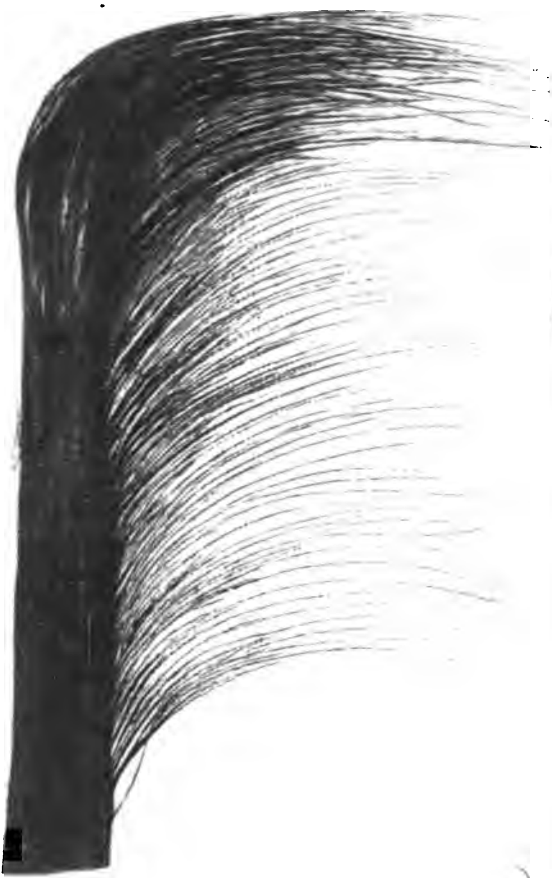
The Heliotype Printing Co. Boston

PLATE XXIII.

YUCCA FILAMENTOSA.

Appendix 21 1883

PLATE XXIV.



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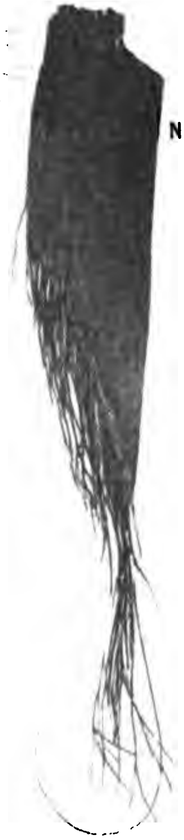

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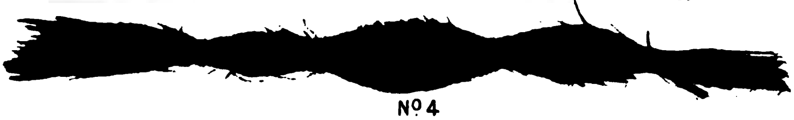

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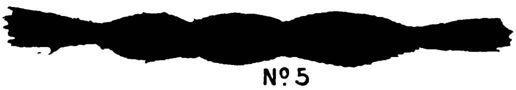

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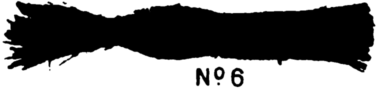
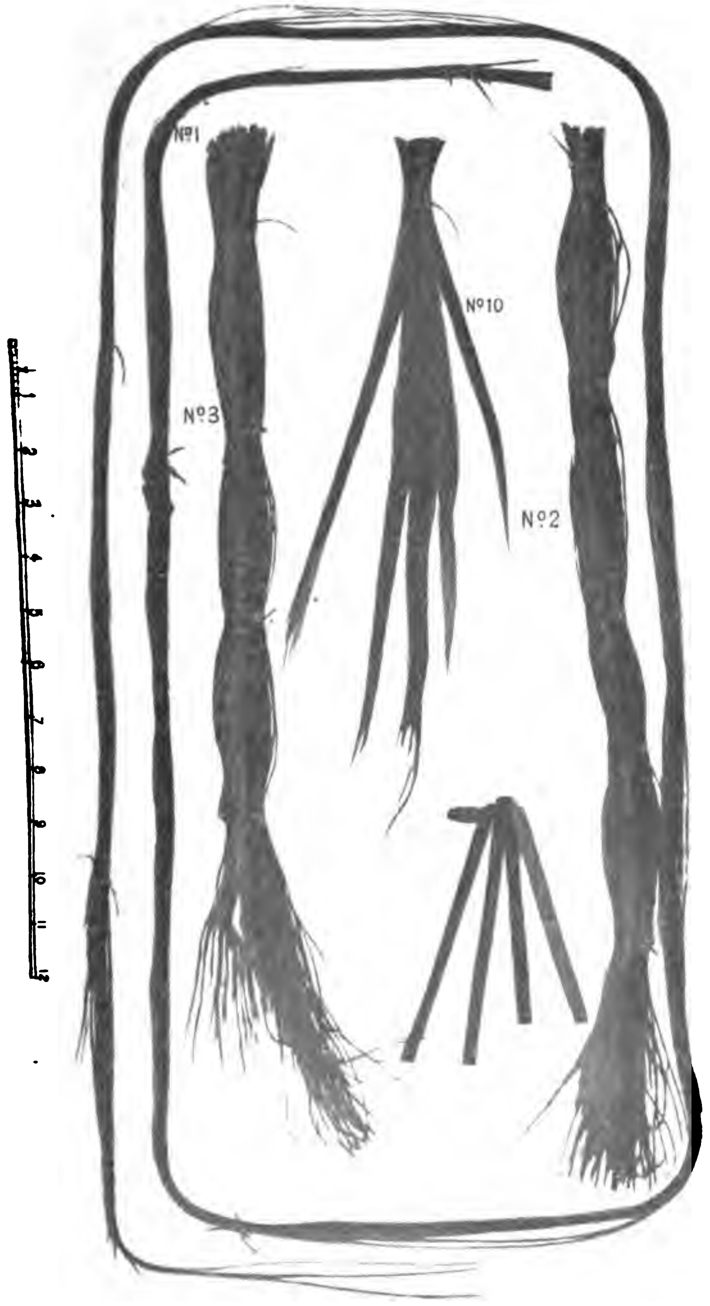


No. 6

Appendix 21 1883

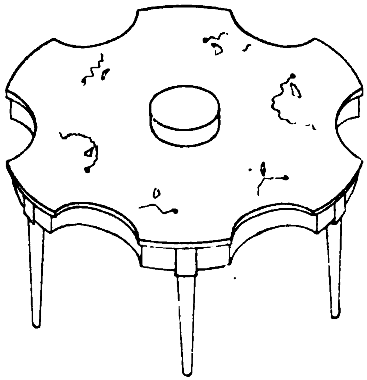
The Heliotype Printing Co London



Appendix 21 1883

The Heliotype Printing Co Boston

PLATE XXVI



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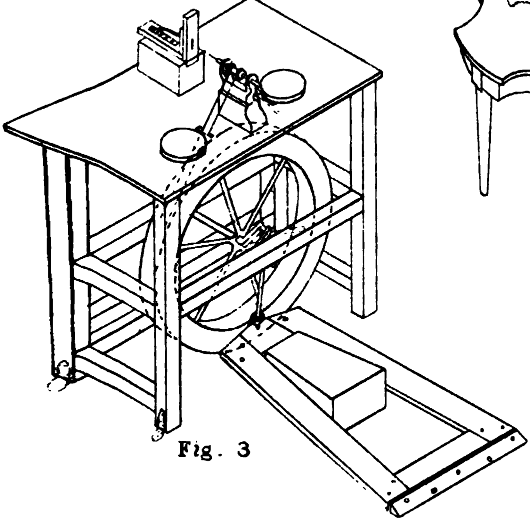


Fig. 3

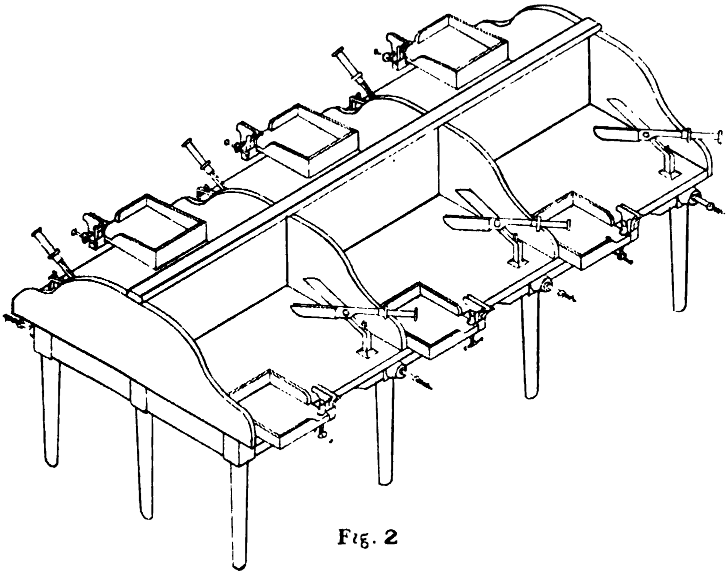


Fig. 2

PLATE XXVII

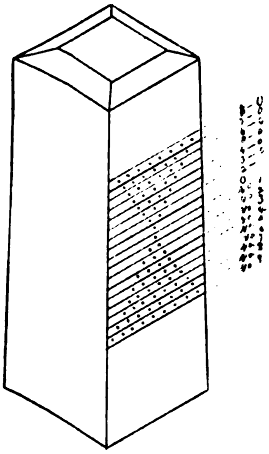


Fig. 3

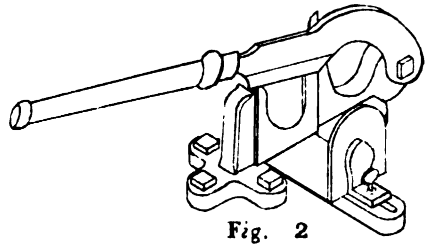


Fig. 2

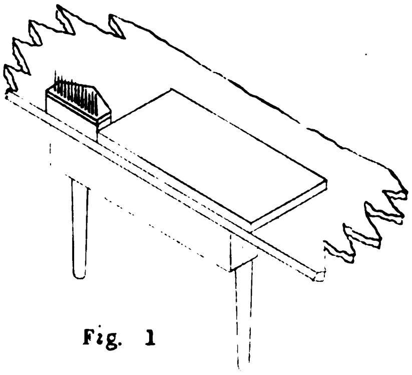


Fig. 1

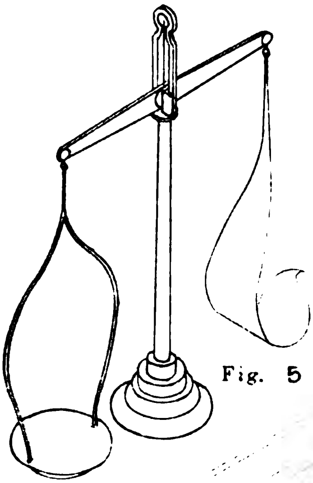


Fig. 5

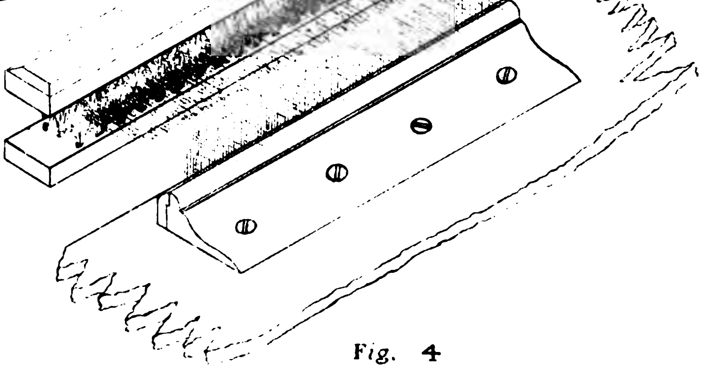
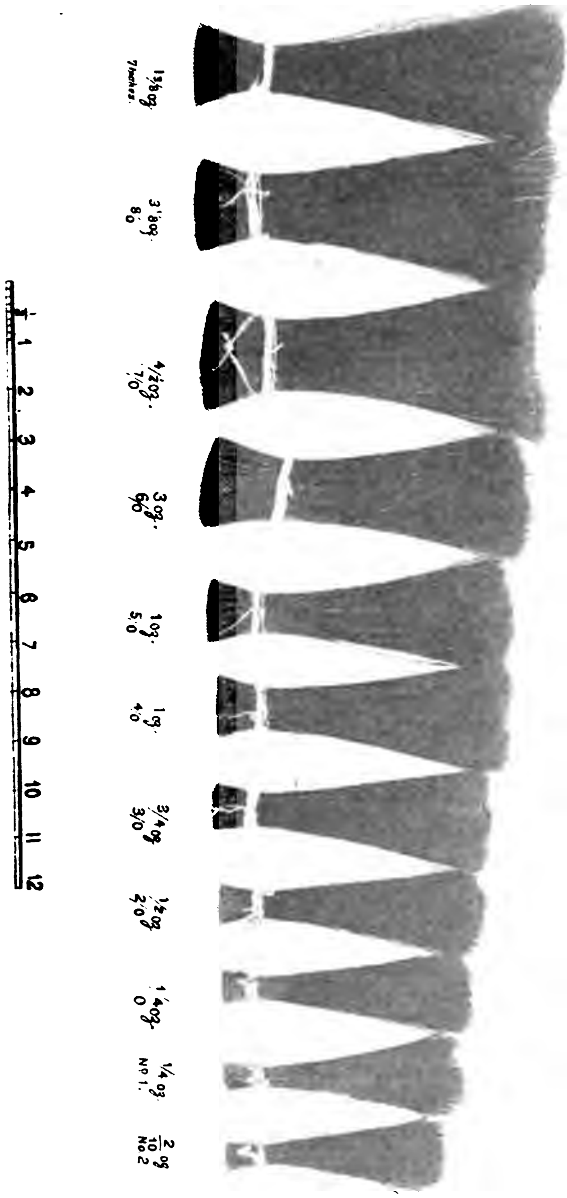


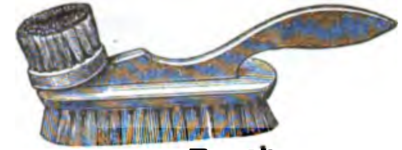
Fig. 4



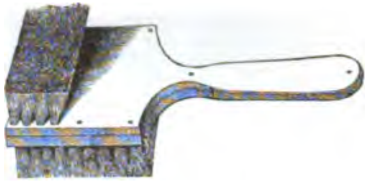
Appendix 21 1883

The Heliotype Printing Co. Boston

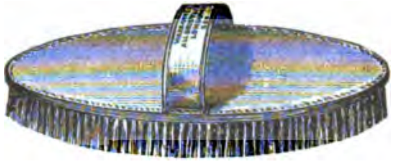
HORSE BRUSHES.



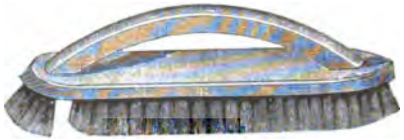
Shoe Brush



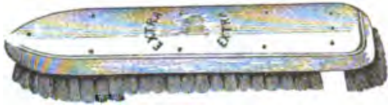
Mane Brush



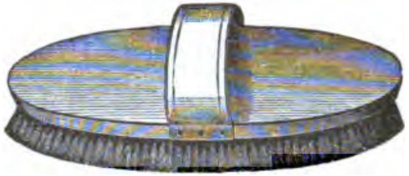
Leather Back Horse Brush



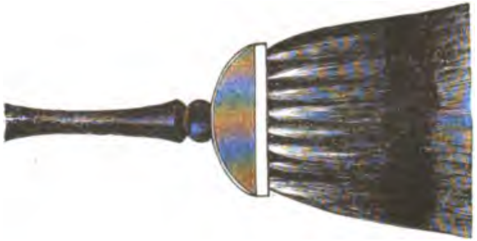
Stove Brush



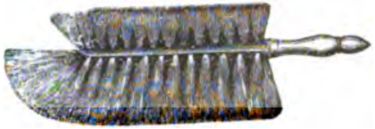
Scrub Brush



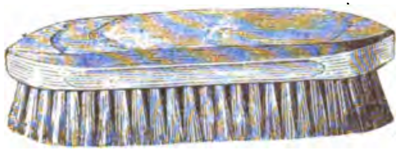
Wood Back Horse Brush



Badger-Hair Blender



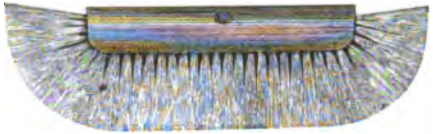
Double or Stair Duster

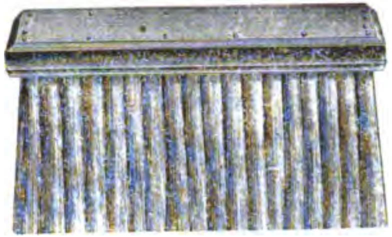


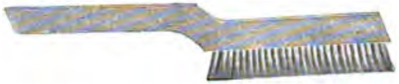
Dandruff, or Water Brush

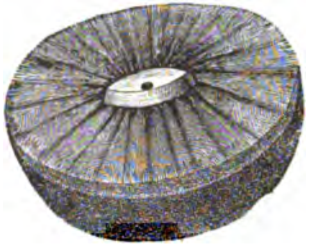
PLATE XXX

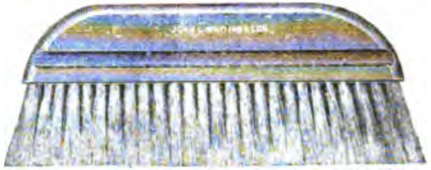
Brick-Striper

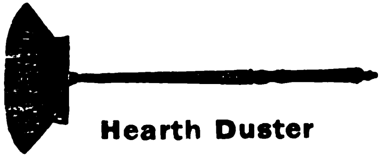

Floor-Brush

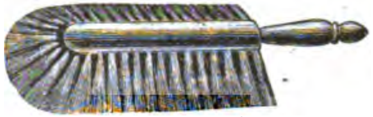

Wall-Stippler


Seaming-Brush


Window-Brush


Paper-Hangers' Smoothing-Brush


Hearth Duster


Bristle Duster

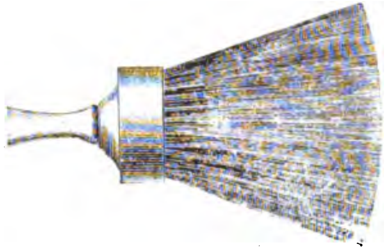
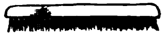

Painters' or Glaziers' Duster

PLATE XXXI

Bottle Brush


SPOKE BRUSH

Handle Shoe Brush

Window Brush

CLOTH BRUSH

Rosewood.

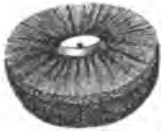
Duster

PISTOL or GUN Brush

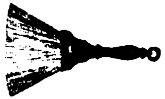
Lye Brush

SHOE POLISHER

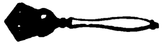
Without Handle


POPE'S EYE

Hair Brush


Ladies' Duster

for Bonnets, Silks, etc.


PLUSH.

BATH BRUSH

Hat Brush

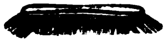
POPE'S HEAD

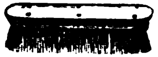
Nail Brush

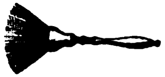
Barbers' Duster

Curved.

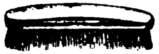
CRUMB BRUSH


BILLIARD BRUSH


Rosewood.


FURNITURE.

Silver-Plate Brush


HARNESS BRUSH

Leather Back

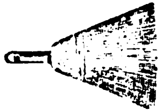
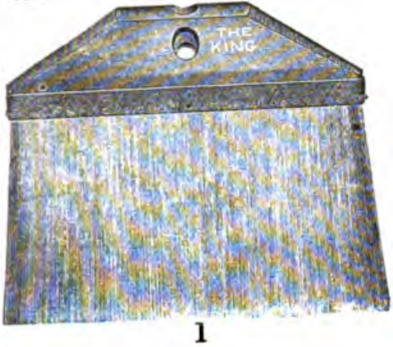

Corn Whisk

PLATE XXXII

WHITEWASH-HEADS.



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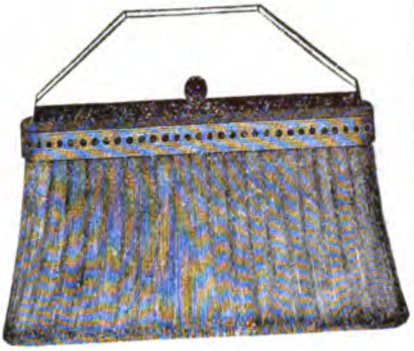

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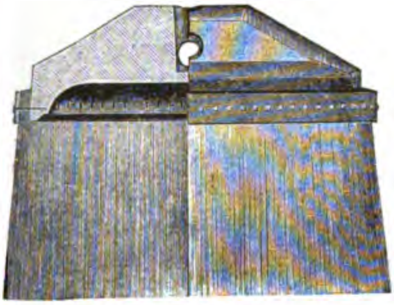

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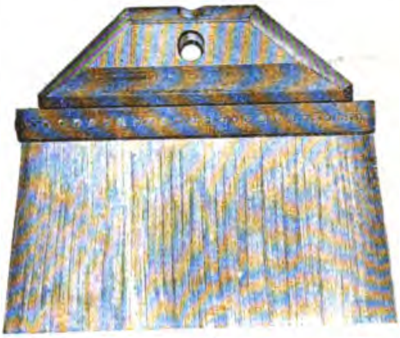

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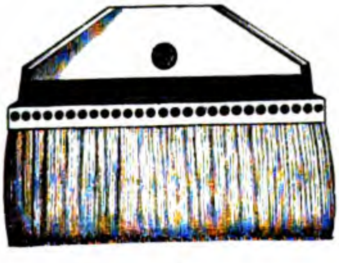

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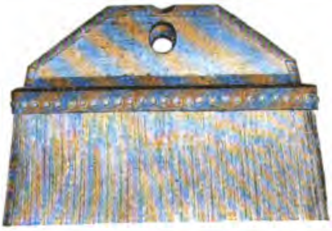
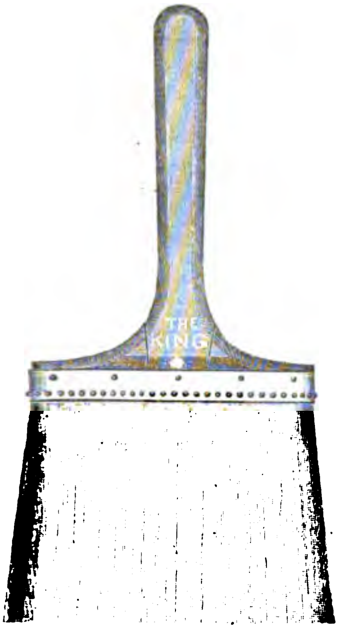
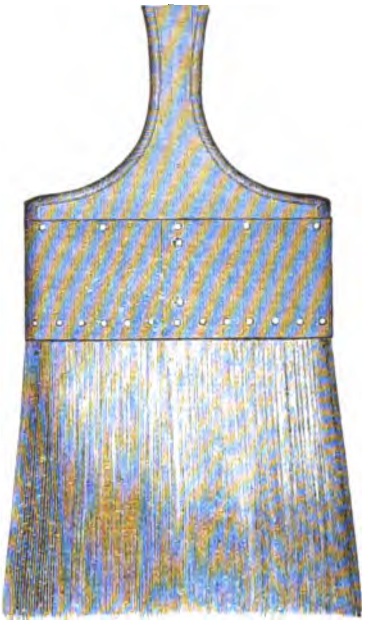


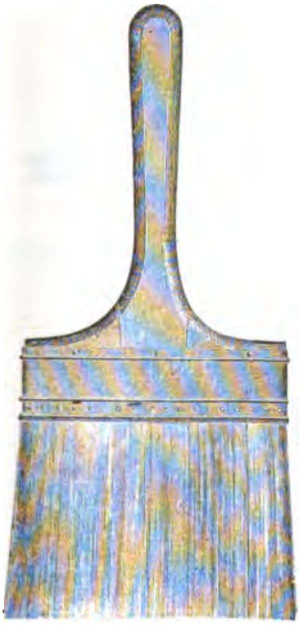
6

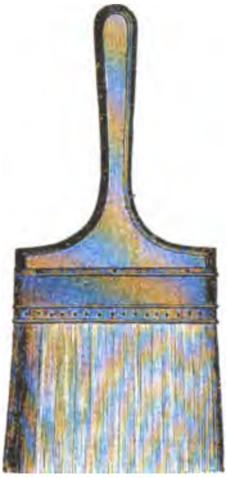
PLATE XXXIII

KALSOMINE BRUSHES.









Kalsomine Head

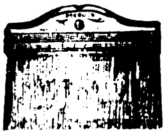
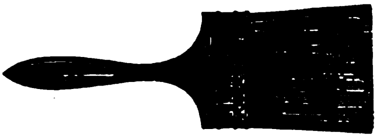


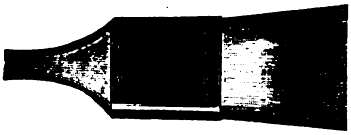
PLATE XXXIV

Wall Paint Brushes.



Wall Paint or Paste Brush.

Gray Paste Brushes.



Chiselled Flat Bristle Varnish-Brush

Single Thick Flat Varnish-Brush

In tin. All French bristles.

Coach Painters

WOOD FILLING.

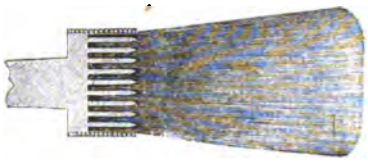
Stucco.

Cornice.

Brass Bound.

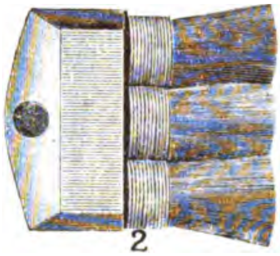
Appendix 21—1883.

Patent Full-Centre Paint-Brush.



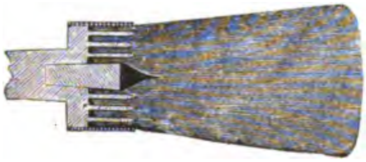
1

Roofing Paint-Brush



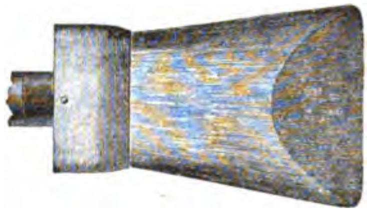
2

Patent Open-Centre Paint-Brush.



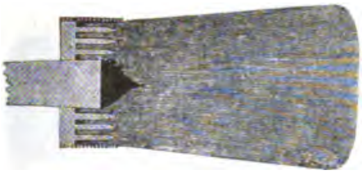
3

Chiselled Varnish-Brush



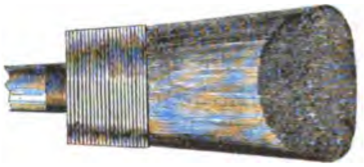
4

Combination Patent Brush.



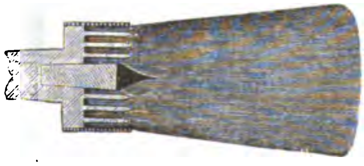
5

Chiseled Carriage Varnish Brush
OVAL. WIRE BOUND.



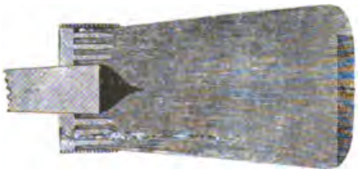
6

Oval Paint-Brush



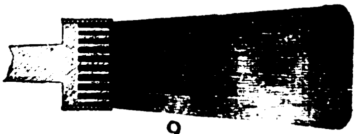
7

Whitings' Pearl Varnish-Brush



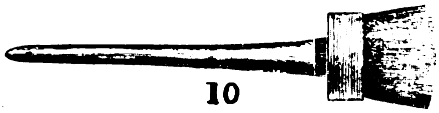
8

Blind-Brush



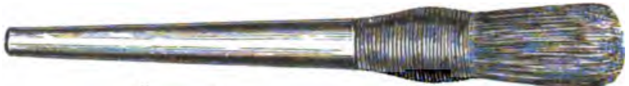
9

Stencil-Brush

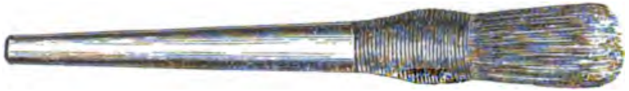


10

French Sash-Tools.
1

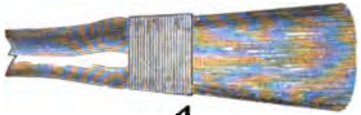


American Sash-Tools.
2



Patent Sash-Tools.
3

Patent Oval Sash-Tool.



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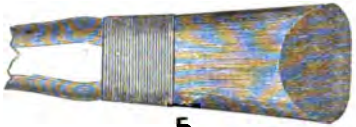
Patent Oval Chiselled Sash-Tool.



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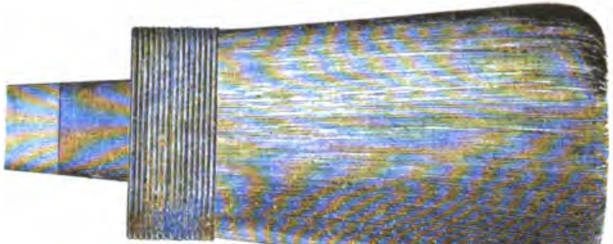
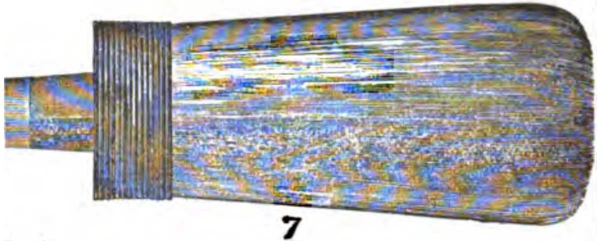
VARNISH BRUSHES.



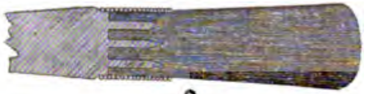
6

PAINT BRUSHES.



7

WHITINGS' IMPROVED PATENT SASH-TOOLS.



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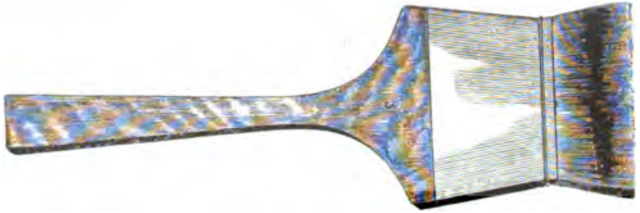
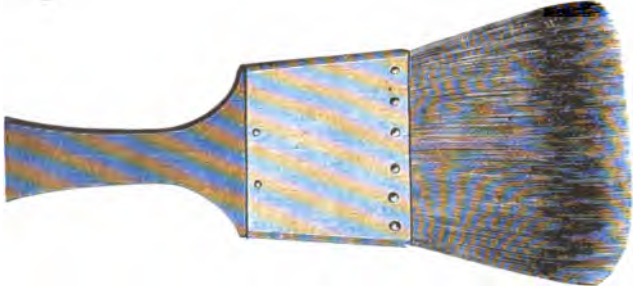
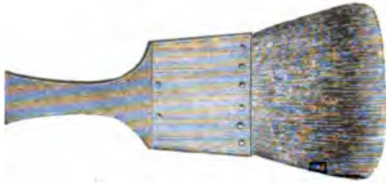


English C. H. Varnish, or Copying Brushes.

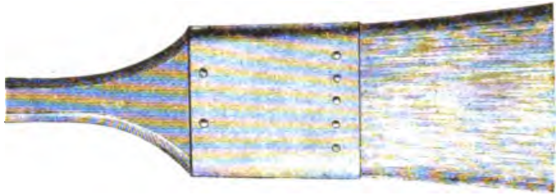


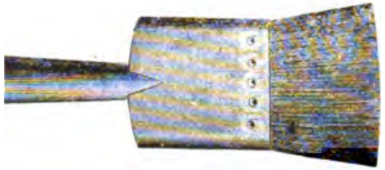
French C. H. Varnish Brushes.



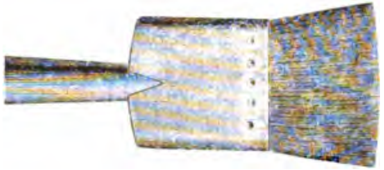
French C. H. Varnish Brushes.

FLAT VARNISH BRUSHES.

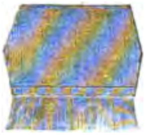




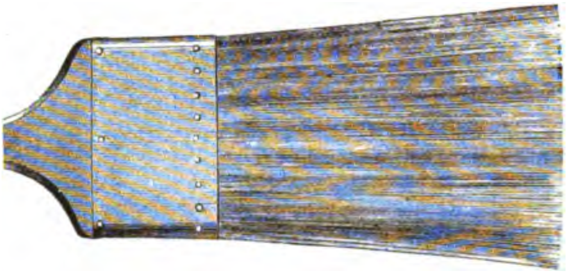
Fitch Flowing Varnish Brush



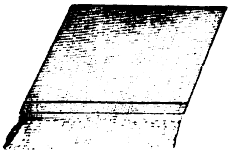
C. H. Flowing Brushes.



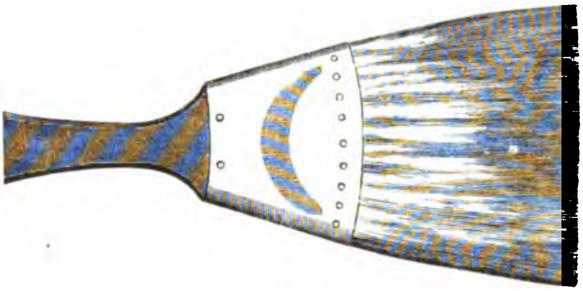
Oak Grainer



Stipplers, or Walnut Grainers.

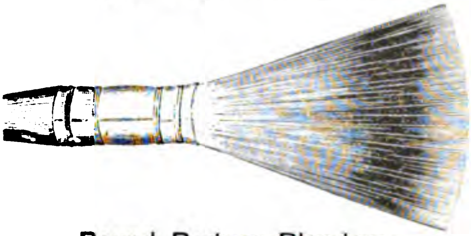


Angular Grainer

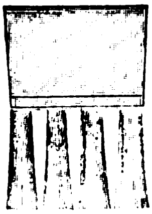


Fan, or Top Grainers.

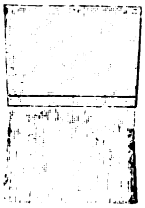
Snake Grainer



Round Badger Blenders.

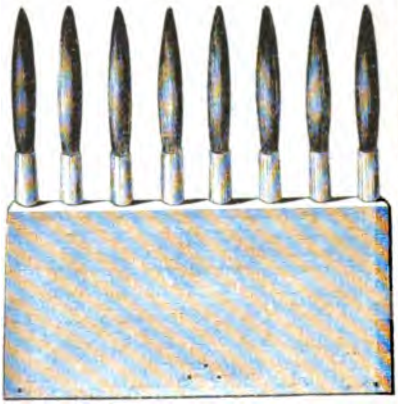


Knotted Grainer

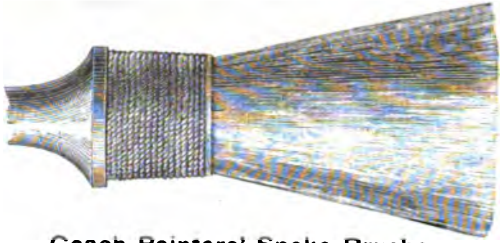


English Grainer

C. H. Mottling Brushes, or Spalter

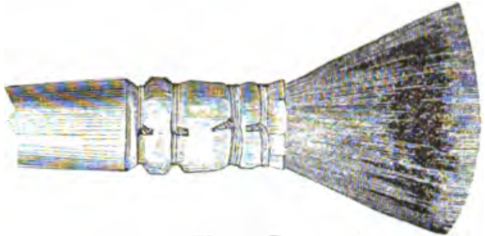


Piped Over Grainers.
Bristle & Sable



Coach-Painters' Spoke-Brushes.

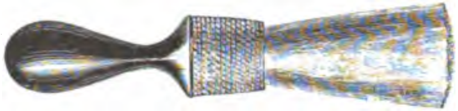
1



Pure Fitch Dusters.

Round. For Gilders.

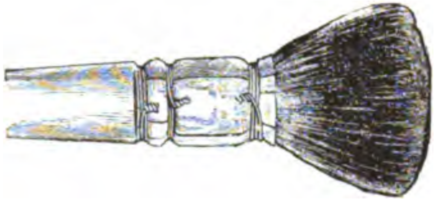
4



Barbers' Shaving Brushes.

Twine Bound.

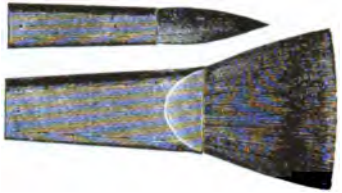
2



C. H. Dusters.

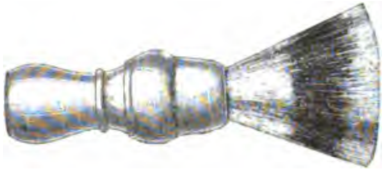
Quill and Wire Bound. Square and Round Point.

5



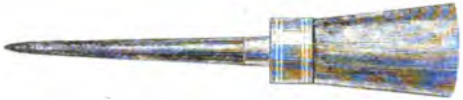
C. H. Lacquering-Brushes.

6



Badger Shaving Brushes.

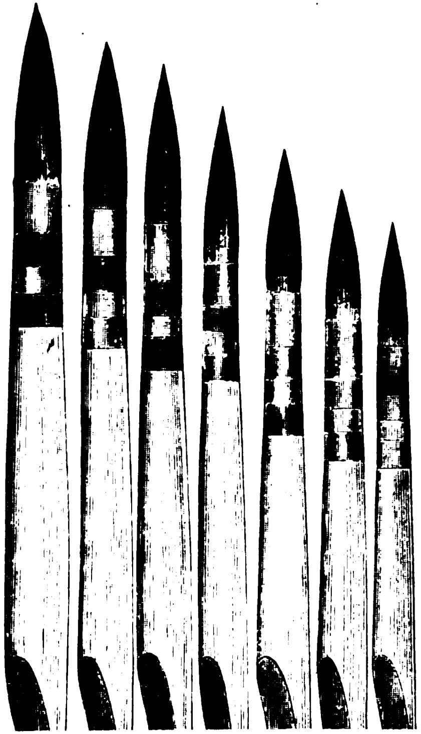
3



Glue-Brushes.

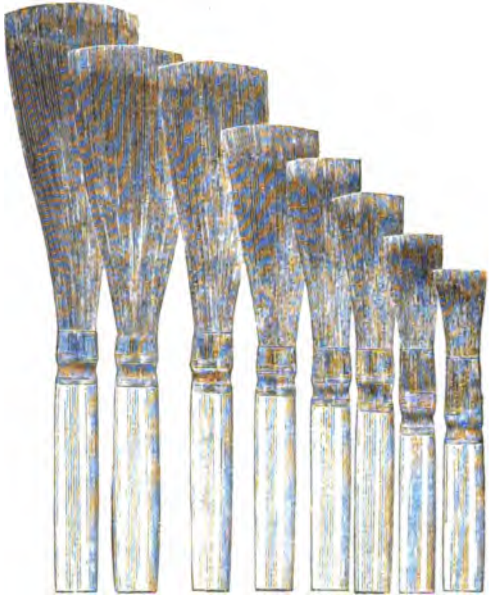
Iron handles.

7



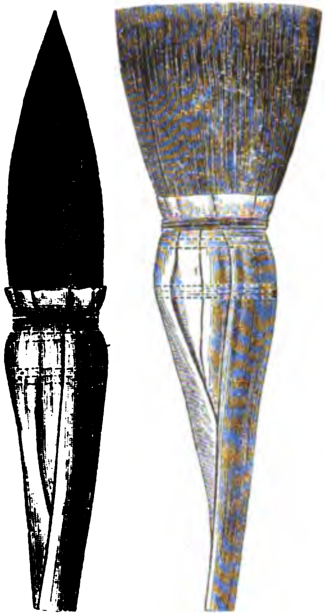
C. H. Swan Quills Miniature Pencils.

CAMEL-HAIR PENCILS.



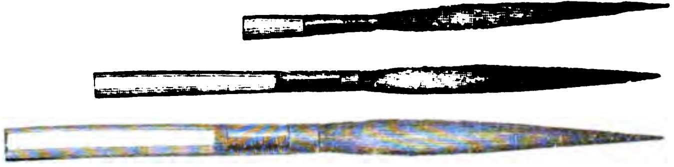
C. H. Pencils, Swan Quills, Lettering and Striping.

CAMEL-HAIR BRUSHES.

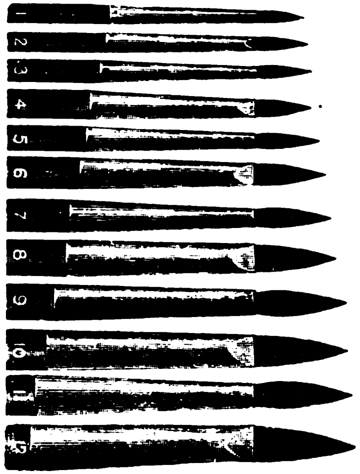


Camel-Hair Split Quill Pencils

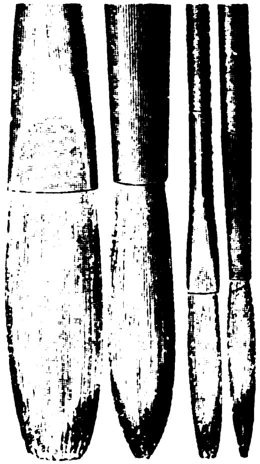
Superfine Artists' Bristle Brushes.



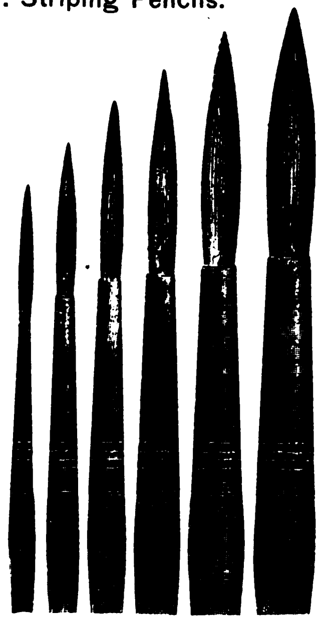
C. H. Striping Pencils.



Artists' Red-Sable Brushes.
For Oil Painting, Photographers, Etc.



Bristle Fresco Brushes.



Ox-Hair Fresco Brushes.
Round and Flat, Polished Handles.

Sable Brushes for Water-Color
In albata ferrules, polished handles.

APPENDIX 22.

REPORT OF MECHANICAL TESTS OF WROUGHT-IRON JACKETS FOR EIGHT-INCH RIFLES.

BY LIEUT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

WEST POINT FOUNDRY,
Cold Spring, N. Y., July 16, 1883.

GENERAL: I have the honor to submit the following report upon mechanical tests for ultimate tenacity, extension, and contraction of original cross-section of specimens taken from the solid forgings for rear sections of jackets made at this foundry under the contract for fifty 8-inch jacketed tubes and muzzle collars, dated June 12, 1883.

On June 6, 1883, the Messrs. Paulding, Kemble & Co. began making the solid forgings for the rear sections of the jackets, from Ulster iron on hand, comprising wrought-iron bands taken from old Parrott guns and an experimental wrought-iron gun made under Mr. Parrott's supervision in 1865. Ten solid forgings were made from this lot of iron.

Subsequently (on June 23) an additional lot of Parrott bands was received from the South Boston Iron Works, and from this lot of iron, with an admixture of B-iron bar ends (scrap), received from the Ulster Iron Works with the bars, under orders for iron to fill the present contract, the remaining fifteen solid forgings were made.

Each forging as made is cylindrical, and double the length required for the rear section of a jacket, being 16.25 inches in diameter and from 32 to 33 inches in length, with an average weight of 1,940 pounds.

Owing to the expense and trouble attendant upon making the forgings of a sufficient surplus length to get out longitudinal specimens for mechanical tests, it was at first determined to take such specimens from the rough and only partly-worked ends which are cut off during the forging to "square" the end of the cylinder.

The following results were obtained with the testing machine at this foundry from specimens taken in this way from the metal used in making the ten forgings first described:

Specimen number.	Original— Diameter.	Original— Length between shoulders.	Weight applied.	Ultimate— Tenacity per square inch of original cross-section.	Ultimate— Contraction of original cross-section.	Ultimate— Extension per inch of length.	Fracture.
	Inches.	*Inches.*	*Pounds.*	*Pounds.*	*Per ct.*	*Inches.*	
1	0.576	2.26	12,200	46,820	39.0	0.27	Fibrous, slightly crystalline.
2	.574	2.25	11,800	45,600	40.3	.315	Same as above.

REMARKS.—This testing-machine is not adapted to any accurate determination of the elastic properties of the test-piece; also, a length of 2 25 inches is as great as the machine will stretch without changing the position of the specimen during the test, a procedure which, by changing the position of the fibers of the specimen with reference to the direction of the strain, invariably gives an unreliable final result.

In making these tests the specimen was not relieved from strain at any time, or allowed to rest. Beginning with 5,000 pounds' weight applied (the initial of the machine), the strain was kept up by constantly balancing the machine, adding successively 100 pounds at a time, until the specimen broke. Finally, the reduced diameter and extension were measured.

Tested in a similar manner, specimens taken from the "ends" in the lot of fifteen forgings mentioned above, gave the following results:

Specimen number.	Original— Diameter.	Original— Length between shoulders.	Weight applied.	Ultimate— Tenacity per square inch of original cross-section.	Ultimate— Contraction of original cross-section.	Ultimate— Extension per inch of length.	Fracture.
	Inches.	*Inches.*	*Pounds.*	*Pounds.*	*Per ct.*	*Inches.*	
1	0.573	2.26	12,500	48,475	39.6	0.265	Crystalline, and fairly fibrous; blistered along one outside element.
2	.576	2.25	12,300	47,200	23.6	.182	Largely crystalline; blistered and cracked across on the exterior; oblique fracture.
3	.576	2.25	12,800	49,120	35.0	.253	Crystalline, and fairly fibrous; blistered and cracked across on exterior.

These two series of tests not being considered entirely satisfactory, the contractors were requested to furnish test-pieces from the *body* of a solid forging. This was accomplished by making one forging of extra length—some 6 inches surplus. From the short cylinder thus obtained three longitudinal specimens were taken: Nos. 1 and 2 from near the outer circumference, and No. 3 from somewhat within the middle of the walls of the section as it would stand in the gun.

In consequence of the well-known effect of intervals of rest and relief from strain during the test (which occur in tests made upon the ordnance machine at Sandy Hook) as tending to elevate both the ultimate tenacity and extension of the specimen, the tests of these specimens were conducted as follows:

No. 1 (outside), precisely as in the first two series given.

No. 2 (outside), after 11,500 pounds' weight had been applied the specimen was allowed to rest 30 seconds between the application of each 300 pounds.

No. 3 (inside), from 5,000 pounds' weight applied upwards the specimen was allowed 20 seconds rest between the application of each additional 300 pounds.

The following results were obtained:

Specimen number.	Original— Diameter.	Original— Length between shoulders.	Weight applied.	Ultimate— Tenacity per square inch of original cross-section.	Ultimate— Contraction of original cross-section.	Ultimate— Extension per inch of length.	Fracture.
	Inches.	*Inches.*	*Pounds.*	*Pounds.*	*Per ct.*	*Inches.*	
1	0.569	2.25	11,900	46,800	32.1	0.231	Fibrous, and slightly crystalline; position, ¼ from end.
2	.5695	2.25	12,800	50,250	45.6	.342	Fibrous, and partly crystalline; position, middle.
3	.569	2.25	11.700	46.010	45.0	.32	Fibrous, and slightly crystalline; position, ¾ from end.

In so far as these results go, they show that the intervals of rest have more effect upon the ultimate extension than upon the tenacity; an anomaly is, however, to be observed in the last series, where the fracture of No. 3, taken from the interior of the forging, exhibits a more fibrous and less crystalline structure than No. 1, taken from near the outer surface, whilst the contrary was to be expected. Again, however, in a forging of this size (16.25 inches diameter), it can scarcely be expected that even specimens taken at a uniform distance from the center will exhibit similar fractures.

APPENDIX 23.

REPORT ON THE FABRICATION OF EIGHT-INCH PROJECTILES.

BY CAPT. D. A. LYLE, LIEUT. C. W. WHIPPLE, AND LIEUT. H. D. BORUP, ORDNANCE DEPARTMENT.

SOUTH BOSTON FOUNDRY,
Boston, December 20, 1882.

Capt. D. A. LYLE,
Inspector of Ordnance, U. S. A.,
South Boston Foundry:

SIR: In compliance with your instructions I have the honor to submit the following notes on the fabrication of the 8-inch Butler cored-shot recently completed at this foundry.

In order to obtain a clearer idea as to what has been done, reference will be made to the method employed in the last contract, a report on which was made at the time of its completion.

The company claimed that to the high quality of iron, then required for the first time, were due the bad results obtained; and, while this no doubt was true to some extent, yet, to me, bad workmanship in the foundry shop proper seemed to be the principal cause, and this view they eventually adopted, in part at least.

The first feature to be noticed is the treatment of the metal. An experimental mixture of pig having been found to give good results as to "tensile strength" and appearance of fracture, it was adhered to as closely as practicable throughout. This was always melted first in the reverberatory furnace, from where it was run into pigs, which were subsequently remelted in the cupola furnace just before casting.

One heat in the reverberatory more than sufficed for a charge in the cupola, the number depending on whether the iron was used for other purposes or not. By this the foreman claims that he can secure greater uniformity. As the grade of iron required is so high, the mixture of pig, in the first instance, cannot be melted in the cupola, but has to be in the reverberatory; and from this latter it is not convenient to take the metal in small ladles.

In the last contract the flasks were at a considerable distance from the furnace, the metal being taken therefrom in large ladles, which, from the want of facilities, could not be rapidly carried to the molds. This permitted the iron to cool to a greater or less extent.

At present the flasks are near the cupola, from which the iron is removed in small quantities and poured before any stiffening sets in. The result is that iron of great strength is obtained, though so long as the old pattern was used blow or sand holes were of too frequent occurrence. As greater care was taken by the company in their inspection of projectiles before finishing, but few defects in material came under my notice. In those cut up for testing, the metal seemed perfectly sound, the fracture of the specimen broken for tenacity being very good, while the mean strength is 31,977 pounds, being 6,977 pounds above that required. There is, however, room for improvement in the molding, too many rejections occurring for badly-shaped heads.

The remedy, I think, lies in more care being taken in the ramming, so as to avoid surfaces of unequal resistance, and in the use of dry sand.

The company, however, prefer green, though the last ten days' work was in skin dried molds, which evidently was advantageous, as few, if any, rejections occurred.

In the preceding contract the heads were very poor; so when work on this began I notified the company that I should as far as possible enforce the limit of variation in the radius of head (0.01 inch), though, of course, it is evident that the inspecting instruments cannot show such a small fraction. The point I had in view was to get *symmetrical* heads, avoiding anything like unequal distribution of metal around the axis. For example, it sometimes happens that the head and cylinder are not tangent. If the surface joining them be great the shot was rejected; if very small and extending all around it was accepted. If this surface existed on one side and the shot was perfect on the other, the projectile would not be accepted, as there would be a want of symmetry. So, too, if there was a wavy outline.

The company claim that .01 inch is too small a variation, and perhaps it is, but they lost no shot by it by my inspection. Their claim for 2½ per cent. is too great. At all events a clear understanding on the subject is of some importance.

Whatever variation is decided upon, the radius of any particular shot should be *constant* for *that* shot, otherwise an unsymmetrical head will result. It also seems to me that in varying the length of the radius its center should be shifted and not the opposite end shortened, as in the latter case the surface of the head will not be tangent to the cylinder, but will be connected with it by an annular surface, while a variation in the position of the center with the other end, terminating at the cylinder, will only result in affecting the length of the shot. But in this last fabrication a small cylinder is formed on the end of the point to compensate for shrinkage, which is afterwards turned off, bringing the projectile down to the proper length.

In the former contract this was not done, so that a large number were not accepted, the whole projectile being too short, or, what is the same thing, the head was. As this is now obviated, there exists no reason, so far as this feature is concerned, for granting any great variation in the radius. No projectiles failed to pass the inspection in this last contract on account of shortness of head due to shrinkage. It therefore appears to me that whatever variation be decided upon, it should be small.

In my last report I stated that I was of the opinion that the effect of blow-holes, &c., in the base could be neutralized by merely increasing the length of the base for sabot, and then, after casting, cutting off the surplus; and as they usually occur near the riser, it might be well to use one small one, as is done at the West Point Foundry, instead of the two large ones used here.

For the first half of the casting, before finishing, the rejections for blow-holes were the more numerous, but afterwards this was nearly perfectly corrected by increasing the length of base as recommended above. With reference to the weight it will be remembered, in the previous contract, that the company were of the opinion that such a high character of iron demanded greater limits in the weight, as so many projectiles were heavier than what was allowed. A pound either way was granted by the Chief of Ordnance, and the same was permitted in this last. But two or three weighed too much, and they were subsequently accepted, a little surplus metal being removed. The mean weight of the entire thousand is 181 pounds, the tenacity being 31,977. Therefore, if the tensile strength of the iron in future contracts be raised to this amount, no reason can exist for a similar demand for increase of limits on account of it.

With reference to the sabot composition, certain proportions are laid down, but the properties of copper and zinc vary for different mines, and even for the same at different dates. The point aimed at, being to get a quality of brass that will take the grooves properly, it might be well at the commencement of an order, or as often as new metal is purchased, to make a few specimens for testing for hardness, &c. In time, sufficient data will be obtainable to enable the Department to say exactly what physical tests the composition must stand. The contractor can then alter his proportions until the tests show that he has the right ones.

About 113 of the projectiles made under the last contract, and which had been rejected principally for erroneous exterior dimensions, were turned down to what was supposed to be proper ones, and were ininspected, 57 being accepted. About 20 of the last day's casting, not being required, were not finished.

Tables giving various data are appended.

In conclusion I would like to say that all the employés concerned have endeavored to turn out the very best work, and that particular credit is due the foreman of the foundry, Mr. Bainbridge, as well as the one in charge of the finishing, Mr. Eldridge.

Very respectfully, your obedient servant,

H. D. BORUP,
Lieutenant of Ordnance.

TABLE A.

Date.	No. 2.—Gridley.	No. 3.—Chatham.	Remelted.	No. 2.—Copé.	No. 2.—Chatham.	Total.	Remarks.
1882.							
Sept. 23	6,000	4,000	8,770	....	....	18,770	Melted in reverberatory and run into pig. Pig subsequently remelted in cupola furnace just before casting.
Oct. 2	2,850	5,100	7,600	....	950	16,500	
7	4,500	3,400	9,100	....	....	17,000	
10	5,100	3,400	8,500	....	....	17,000	
12	6,000	4,500	8,730	....	....	19,230	
14	4,820	4,130	9,380	....	....	18,330	
17	....	4,300	8,700	5,000	....	18,000	
21	....	4,800	9,370	6,700	....	20,870	
24	....	4,800	9,600	6,720	....	21,120	
26	....	4,800	9,300	6,720	....	20,820	
28	....	4,800	9,300	6,700	....	20,800	
Nov. 1	....	3,260	7,800	5,000	....	16,060	
3	....	3,200	7,800	5,000	....	16,000	
6	....	3,200	7,800	5,000	....	16,000	
9	....	2,900	7,000	4,300	....	16,200	
14	....	4,600	7,200	5,400	....	17,200	

TABLE B.

Date.	Number of casting.	Number cast.	Tenacity.	Specific gravity.	Hardness.	Date.	Number of casting.	Number cast.	Tenacity.	Specific gravity.	Hardness.
1882.			*Pounds.*			1882.			*Pounds.*		
Sept. 26	1	30	34, 130	7. 2412	16. 03	Nov. 4	25	32	27, 498	7. 2450	17. 08
Oct. 9	2	30	34, 572	7. 2557	....	6	26	31	28, 350	7. 2649	....
10	3	32	28, 977	7. 2083	....	7	27	32	26, 526	7. 2300	....
11	4	32	33, 599	7. 2217	....	8	28	32	29, 276	7. 2366	....
12	5	32	33, 881	7. 2531	21. 17	9	29	32	35, 714	7. 2866	....
13	6	32	32, 968	7. 2096	....	10	30	30	30, 404	7. 2338	21. 17
14	7	32	32, 963	7. 2533	....	11	31	32	33, 664	7. 2452	....
16	8	32	33, 688	7. 2351	....	13	32	32	32, 804	7. 2714	....
17	9	32	30, 651	7. 2140	....	14	33	32	36, 429	7. 2975	....
18	10	32	28, 039	7. 2100	15. 43	15	34	27	26, 348	7. 2109	....
19	11	32	31, 124	7. 2164	....	16	35	22	26, 037	7. 1929	17. 99
20	12	32	37, 706	7. 2012	....	17	36	32	30, 991	7. 2611	....
21	13	32	27, 640	7. 1698	....	18	37	32	36, 605	7. 3410	....
23	14	32	32, 276	7. 2401	....	20	38	32	38, 839	7. 2520	....
24	15	32	36, 131	7. 2869	21. 77	21	39	32	39, 563	7. 2993	....
25	16	31	34, 745	7. 2422	....	22	40	32	37, 013	7. 2715	21. 17
26	17	32	33, 334	7. 2085	....	23	41	32	33, 889	7. 3171	....
27	18	32	31, 919	7. 2301	....	24	42	42	25, 642	7. 1972	....
28	19	32	27, 498	7. 2876	....	25	43	32	33, 825	7. 3310	....
30	20	32	31, 530	7. 2218	18. 98	27	44	32	39, 343	7. 3417	....
31	21	31	27, 640	7. 2135	....	28	45	43	26, 790	7. 1532	....
Nov. 1	22	32	30, 240	7. 2258	....	29	46	43	30, 858	7. 2318	15. 43
2	23	32	29, 443	7. 2580	....	30	47	42	25, 741	7. 1666	....
3	24	32	38, 905	7. 3046	....	Dec. 1	48	43	29, 188	7. 2166	....

TABLE C.—*Projectiles.*

	Number cast.	Used for tests.	Finished.	Inspected.	Accepted.	Rejected.					
						After finishing.					
						Erroneous dimensions—					
						Of head.	Of cylinder or base.	Of interior cavity.	Eccentricity.	Material.	Total.
Present contract...............	1, 565	46	1, 107	1, 107	943	63	42	27	8	24	164
Last contract...................	113	....	113	113	57	31	9	......	1	5	56
Total.....................	1, 678	46	1, 220	1, 220	1, 000	94	51	27	9	29	220

	Rejected.				Number unfinished.	Number weighing—					
	Before finishing.										
	Material.	Erroneous dimensions.	Total.	Grand total.		178 pounds.	179 pounds.	180 pounds.	181 pounds.	182 pounds.	183 pounds.
Present contract..............	331	60	391	555	21	......	......	......	......	......	......
Last contract...................	......	......	......	56	......	......	......	......	......	......	......
Total.....................	331	60	391	611	21	6	39	193	391	255	116

NOTE.—These figures for rejecting before finishing are only approximate.

TABLE D.—*Sabots.*

Number inspected	1,029
Number rejected	29
Defective material	27
Erroneous dimensions	2
Number accepted	1,000
Number weighing—	
9 pounds, 10 ounces	3
9 pounds, 11 ounces	4
9 pounds, 12 ounces	10
9 pounds, 13 ounces	63
9 pounds, 14 ounces	198
9 pounds, 15 ounces	275
10 pounds	277
10 pounds, 1 ounce	128
10 pounds, 2 ounces	32
10 pounds, 3 ounces	10

INSPECTION SERVICE, UNITED STATES ORDNANCE DEPARTMENT.

CLASS 4.—PROJECTILES FOR 8-INCH M. L. RIFLED GUNS.

Inspection report of 8-inch ogival-headed Butler cored shot for 8-inch rifle, made for the United States Ordnance Department by Paulding, Kemble & Co., at Boston, Mass., under contract of the Chief of Ordnance, dated July 6, 1882.

Subject of measurement.	Prescribed dimensions.	Allowed variations.
Projectile:		
Length of cylindrical portion of body	10''.2	+2 per cent.
Length of head	9''	−2 per cent.
Length of base for sabot	1''.7	±0''.05
Total length of projectile	19''.5	1 per cent.
Diameter of cylindrical portion	7''.95	±''.01
Diameter of base over threads	6''	....
Radius of head	12''	±0''.01
Thickness of bottom	2''.25	±0''.10
Length of interior cavity	10''.25	±0''.10
Thickness of walls at thinnest point	2''.225	....
Eccentricity of axis of interior cavity	0	±0''.10
Diameter of fuze (or screw-plug) hole	1''.5	±0''.01
Pitch of thread on fuze (or screw-plug) hole	8''	....
Length of thread on fuze (or screw-plug) hole	2''	....
Diameter of hole for shell-hooks	0''.5	....
Depth of hole for shell-hooks	0''.5	....
Distance from base of projectile	10''.375	....
Weight of projectile ....pounds	170	±1½ per cent.
Sabot:		
Height of sabot	1''.7	±0''.01
Exterior diameter of sabot	7''.95	±0''.01
Interior diameter of sabot	5''.75	±0''.01
Maximum thickness of outer lip	0''.23	±0''.01
Minimum thickness of outer lip	0''.23	±0''.01
Depth of canneluro	0''.8	±0''.01
Maximum width	1''.1	±0''.01
Weight of sabot ....pounds	9¼	....
Weight of sabot and projectile ....do	180	±1½ per cent.

Number of 8-inch Butler cored shot examined	1,220
Number rejected for erroneous dimensions of head	94
Number rejected for erroneous dimensions of cylindric body or base	51
Number rejected for erroneous dimensions of interior cavity	27
Number rejected for eccentricity of interior cavity	9
Number rejected for defects in material or finish	29
Total number rejected	220
Total number accepted	1,000
Weight of heaviest one accepted ......lbs	173

Weight of lightest one accepted ..lbs	168
Weight of total number accepted do	171,248
Mean weight of projectile ......do	171
Number of sabots examined	1,029
Number of sabots rejected for erroneous dimensions	2
Number of sabots rejected for defects in material or finish	27
Total number of sabots rejected	29
Number of sabots accepted	1,000
Weight of total number accepted .lbs	9,955
Mean weight of sabot .... oz	9.15
Weight of total number of shot and sabots accepted ....lbs	181,198

Physical properties.

Specimen.	Actual density.	Prescribed tenacity.	Actual tenacity.	Hardness.	
Maximum	7.417	....	39,563	21.77	Wade's unit.
Minimum	7.1532	24,250	25,642	15.43	
Mean	7.2438	25,000	31,977	18.62	

REMARKS.—In process of shipment to the Watertown Arsenal.

I certify that I have carefully inspected the above-noted projectiles, and that they conform to the dimensions prescribed within the variations allowed, and, further, that the terms of the contract as to material and workmanship have been complied with in their manufacture.

D. A. LYLE,
Captain of Ordnance, Inspector.

Date of inspection, December 15, 1882.

Record of 8-inch Butler shot cast at the West Point Foundry, under contract of the Chief of Ordnance, dated July 6, 1882, by Lieut. C. W. Whipple, Ordnance Department.

Date.		Number cast.	Charge of iron in cwt.						Tenacity.	Density.	Condemned before completion.					
			Gore No. 2.	Gore No. 3.	Gore No. 4.	Poughkeepsie.	Scotch No. 1.	Scrap (shot).			Eccentricity.	Draw at head of core.	Defects in material.	Broken core.	Erroneous dimensions.	Total.
1882.									*Pounds.*	*Per ct.*						
Sept.	6	32	30	30	....	10	....	....	31,243	7.1853	......	20	......	......	......	20
	8	32	24	31	....	10	....	...	26,883	7.2061	......	9	...	1	......	10
	9	32	26	14	....	10	....	16	26,301	7.1693	......	1	3	......	......	4
	11	32	25	16	....	10	....	16	31,363	7.2311	......	......	......	......	......	......
	12	32	27	16	....	10	....	16	27,418	7.1916	......	......	......	1	......	1
	13	32	26	16	....	10	....	16	25,900	7.2673	......	......	2	......	1	3
	14	32	27	14	....	10	....	16	28,043	7.3069	......	......	2	......	......	2
	15	32	30	14	....	10	....	14	24,423	7.2898	......	......	1	......	......	1
	16	32	31	13	....	10	....	14	26,838	7.2663	......	......	......	......	......	......
	18	32	30	13	....	10	....	14	29,221	7.2864	......	......	1	......	......	1
	19	32	31	13	....	....	9	14	28,723	7.1880	......	......	......	......	......	......
	20	32	31	13	....	....	9	14	25,987	7.1459	......	......	......	1	......	1
	21	32	31	14	....	....	8	14	25,672	6.9994	......	......	1	......	......	1
	22	32	33	16	....	....	10	16	27,779	7.1823	......	......	2	......	......	2
	23	32	28	17	....	....	8	14	24,519	7.1227	......	......	1	......	......	1
	25	32	28	17	....	....	8	14	24,325	7.1357	......	1	......	......	......	1
	26	32	27	18	...	....	7	14	26,435	7.1308	....	......	1	......	......	1
	27	32	27	19	....	....	7	14	26,659	7.1377	1	......	1	......	......	2
	28	32	26	21	....	....	6	14	24,954	7.1165	......	......	1	......	......	1
	29	32	23	23	....	7	....	14	25,941	7.1301	......	......	3	......	......	3
	30	32	22	22	....	7	....	16	26,076	7.1406	......	1	......	......	......	1
Oct.	2	32	20	20	6	7	....	16	30,378	7.2817	......	1	2	......	......	3
	3	32	16	24	6	7	....	14	29,352	7.2660	......	......	......	......	......	......
	4	32	28	36	10	10	....	20	26,121	7.1552	......	......	1	......	......	1
	5	32	21	20	5	7	....	14	26,076	7.1483	......	1	......	......	......	1
	6	32	21	20	5	7	....	14	27,737	7.2418	......	......	......	......	......	......
	7	32	20	22	4	7	....	14	25,761	7.3009	......	......	2	......	......	2
	9	32	21	21	4	7	....	14	29,571	7.3180	......	......	......	......	......	......
	14	32	20	22	4	7	....	14	25,943	7.1795	......	......	......	......	......	......
	16	36	24	24	4	7	...	14	27,467	7.1921	......	......	1	......	......	1
	17	36	22	22	4	7	....	14	29,082	7.2858	......	......	2	......	......	2
	18	36	22	22	4	7	....	14	28,723	7.2811	1	......	......	......	......	1
	19	36	22	22	4	7	....	14	24,739	7.1039	......	2	......	......	......	2
	20	36	22	22	4	7	....	14	26,047	7.2679	......	1	......	......	......	1
	21	36	22	22	5	7	....	14	28,364	7.2520	......	......	......	......	......	......
Total condemned before completion by inspector											2	37	27	3	1	70
Thrown out by foreman of finishing shop for various defects during completion											......	......	26	......	......	26
Condemned after completion by inspector											36	......	5	......	4	45
Total condemned											38	37	58	3	5	141
Total number of shot cast, 1,141.[*] Total number of shot accepted, 1,000. Percentage of losses											3.33	3.24	5.08	0.26	0.44	12.35

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[*] 19 additional shot finished, but not inspected.

C. W. WHIPPLE,
Lieutenant of Ordnance.

APPENDIX 24.

DESCRIPTION OF THE UNITED STATES TESTING MACHINE AT WATERTOWN ARSENAL.

BY CAPT. J. PITMAN, UNDER THE DIRECTION OF MAJ. F. H. PARKER, ORDNANCE DEPARTMENT, COMMANDING.

(12 plates.)

The United States Government testing machine is the invention of Mr. A. H. Emery, of New York, and its construction was completed in 1879.

It is a horizontal hydraulic machine, has a capacity of 800,000 pounds for strains of tension and compression, and can test specimens of any length up to 30 feet, and of width not exceeding 30 inches. By a slight modification it is adapted for compression tests of 31 feet 2 inches in length, and for tensile tests of eye-bars 37 feet 3 inches from center to center of eyes.

The principal parts are the platforms of a hydraulic scale at one end and a straining press at the other, connected by two 8½-inch wrought-iron screws 48 feet long, supported horizontally 47 inches above the floor and 50 inches apart. Four bronze nuts working upon these screws are in contact with either end of the press, and are connected by gearing with a splined shaft below, extending between tracks parallel to the screws. This shaft is actuated by a live head at one end worked by steam-power.

The *straining press* has a cylinder 20 inches diameter and 24 inches stroke. It is mounted on a truck which runs on the tracks between the screws and is brought nearer to or farther from the scale platforms, to accommodate different lengths of specimens, by operating the live head which revolves the shaft, which in turn works the bronze nuts.

The *scale platforms* are vertical, and capable of a slight longitudinal movement, being suspended and restrained by vertical and horizontal springs which also serve to give the platforms an initial pressure against each other. Between the platforms are placed, symmetrical with the line of traction, four sealed columns of liquid, called *supports*, which, when the platforms are pulled or pressed together by the movement of the piston of the straining press attached to the other end of the specimen being tested, receive the strain and transmit it through $\frac{1}{10}$-inch copper tubes to four similar but smaller *supports* in the scale case. These act by their expansion on levers, raising a vertical rod which presses against the *beam of the scale.* The weights required to balance this beam indicate the strain on the specimen in the machine.

The hydraulic power is supplied by a *steam-pump* working into an *accumulator*, instead of into the straining-press cylinder direct. This avoids the pulsations caused by pumping, and facilitates the manipulation of the machine. The *accumulator* has a vertical 10-inch cylinder and ram; the latter of which in turn contains a 5½-inch ram. Either ram may be used to lift one, two, or three heavy masses of masonry, which are keyed, when desired, to a vertical wooden post resting on the inner and smaller ram. This arrangement allows of a variation of pressure from 380 to 3,400 pounds per square inch, or on one face of the piston of the straining-press cylinder—having the largest available area—a pressure varying from 119,400 to 1,068,000 pounds, and on the other face a pressure varying from 89,500 to 801,100 pounds. The larger limit occurs in the case of compression, and the smaller in the case of tension tests. Either ram and one or more of the weights can be used, depending upon the strength of the specimen.

The liquid (sperm oil) being pumped from a tank into the accumulator, the pressure obtained by means of the weights is transmitted to either end of the press cylinder by *jointed pipes* controlled by valves in the scale case, the handles of which are convenient to the operator's hands.

Attached to the piston rod of the straining press, and mounted on a truck so that it can move with the press, is the *movable holder*. A like but *stationary holder* is attached to the scale platform, but is balanced on vertical rods. These holders, consisting each of three heavy castings, are furnished with hydraulic presses, and have for their function to grasp between their jaws each an end of the specimen to be tested.

In addition to the scale beam, which weighs the load received at one end of the machine, *pressure gauges* indicate the strain in the cylinder. Like gauges also indicate the pressure of the jaws upon the specimen.

Underlying the whole machine is a solid masonry *foundation*, upon which it rests. The tracks are bolted to this foundation, and are laid in sulphur bearings. At the platform end there is a thick cast *bed plate*, on the same level as the tracks, likewise laid in sulphur, and firmly fastened to the foundation. Upon this bed plate rests a large cast-iron box-like *stanchion*, upon which are suspended by springs and rods the platforms themselves and their holder. It also has four *pillow blocks*, which support one end of the great screws; their other ends being supported by spring struts. There are also intermediate *rests* for the screws, and *bearings* for the splined shaft, which are so pivoted and balanced as to turn down out of the way of the movement of the press and its holder.

All the parts above the *bed plate* are stationary when in use, as regards their relative positions only, the whole system being allowed a slight longitudinal motion, which is gradually checked by buffer springs. This prevents injury from the shock of reaction, resulting from the sudden breaking of the specimen.

From the foregoing the general construction, arrangement, and operation of the machine may be understood.

The weighted *accumulator* (Plate III) forces the liquid into the *straining press* (A, Plate II), moving its piston in or out, according as it is desired to pull or compress the specimen, to one end of which it is connected. The *scale platforms* (B, Plate II) receive the strains transmitted through the specimen and are pressed together, either by pulling the outer one against the inner one by means of a heavy *link* (C, Plate II), or by pushing in the reverse direction, one of the platforms—as is required for either tension or compression test—for the time being becoming the *bed* resting against a shoulder of the screws. This strain, received upon the hydrostatic presses in the *supports* (D, Plate II), is transmitted to the *scale beam* (*a*, Plate X), where it is weighed. The great longitudinal *screws* (E, Plate II), separate and hold in position the press and the scale or receiving end. The *holders* (F and F′, Plate II) which are between the press and the platforms, and connected with them, grasp each an end of the specimen. These can be, and are, for certain long specimens, dispensed with.

The *bed-plate* (G, Plate II), the *tracks* (H, Plate II), the *stanchion* (I, Plate II), the *trucks* (J, Plate II), the *rests* (K, Plate II), for the screws and the *bearings* (L, Plate II), for the shaft (M, Plate II), the *pipes* (N, Plate II), the *gauges* (P, Plate II) and other minor parts, are all shown in the plates, and their uses are obvious.

This testing machine is thought to have over any other an advantage as regards capacity, delicacy, accuracy, convenience of application and manipulation, and impunity from injury due to the shocks of recoil.

As regards the last point, it will be seen that the large screws are strained equally, but in the reverse direction with the specimen being tested, they being compressed when the latter is extended, and *vice versa.* When the specimen suddenly breaks, the screws free themselves by expanding or contracting longitudinally, moving the two ends of the machine in opposite directions. The stanchion, with all it supports, moves on the bed-plate, and the press and its holder on the tracks. The inertia will subject the screws to a reverse strain, approximating in amount to the strain received from the press. To restrain these reactions, and in order that the parts may always come to rest in their proper positions, the horizontal *buffer-springs* (R, Plates IV and V), and vertical rods are provided. Showing the efficiency of this arrangement, and as exhibiting the capacity and accuracy of the machine, it may be mentioned that when first completed a 5-inch round bar of wrought iron was fractured, requiring over 700,000 pounds tension; from this a change was immediately made to a specimen which broke with one pound tension, and the scale correctly indicated the load in each case. The sensitiveness of the gauges and scale beam is extreme, a slight pressure of the hand upon the platforms or the strain necessary to break a hair being transmitted in a perceptible degree.

It has been in use since February, 1879, during which time it has tested nearly 8,000 specimens, varying greatly in the character of their material tested, and from those large pieces requiring the full power of the machine to those of trifling dimensions and strength. From this work much useful information has necessarily been derived.

Below is given more detailed descriptions of the parts, with full reference to the drawings appended.

LIST OF PLATES.

I.—The testing machine.
II.—General drawing of testing machine.
III.—The accumulator.
IV.—The stanchion, scale platform, and hydraulic holder.
V.—Buffer box.
VI.—Straining press.
VII.—Hydraulic holder.
VIII.—Scale supports.
IX.—Hydraulic scale, first levers.
X.—Hydraulic scale, weighing beam, and weights.
XI.—Holder gauges.
XII.—Flexible joint.

THE PUMP.

It is formed from a steam-pump of the Knowles pattern, by prolonging the piston-rod through both ends of the steam cylinder, and removing the ordinary pump cylinder, which is replaced by a brass double-acting pump (1½-inch diameter), the piston-rods of which are secured to the steam piston-rod by rods and cross-heads. Beyond the steam cylinder and in the prolongation of its axis is bolted a second double-acting brass pump (⅞-inch diameter), the piston-rods of which are arranged as at the other end. Either pump can be used, for by means of a valve the oil may be made to circulate freely through the low-pressure pump, and thereby making only the high-pressure pump force the oil into the accumulator.

THE ACCUMULATOR.

(Plate III.)

This consists of a hollow vertical cylinder, *a*, open at the top, and covered by a cap, inside which is fitted a 10-inch ram, *b*. This in turn receives a ram, *c*, 5½ inches in diameter, on the head of which rests a vertical wooden column, *d*, having three rectangular horizontal holes passing through the axis about equidistant, for the purpose of keying on the weights. Surrounding this column, and moving between four vertical guides, *e*, are three masses of masonry. By means of keys these are connected with the column, and are raised with the same.

Oil enters the larger cylinder at the bottom, *f* raising the larger ram. A valve at option closes this pipe and forces the oil to pass into a jointed pipe, *g*, and thence to the top of the smaller ram, whence it passes by means of a tube in the axis of the same to the bottom of the smaller cylinder, thus raising the smaller ram. A safety valve, *h*, operated by a rod attached to the head of the smaller ram, allows the oil, when at a certain height, to pass into the tank, thereby preventing the rams from being pumped out of the cylinder.

THE TRACK.

(H, Plate II.)

This is of iron, cast in sections, and bolted in a level position to the masonry foundation, so that the upper surface is flush with the floor.

THE BED-PLATE.

(G, Plate IV.)

This is a heavy plate of cast iron having along the two sides raised flanges, on the interior surface of which is a groove. This is also bolted to the masonry foundation, so that the upper surface is level and in the prolongation of the plane of the upper surface of the track. It is tapped to receive the buffer spring attachment.

THE STANCHION.

(I, Plate IV.)

This is a box-like casting, *a*, having on the lower surface flanges which enter the grooves in the bed-plate. The stanchion is also secured by four long bolts, *b*, passing through tubes and attached to anchor plates near the bottom of the foundation. These, with the grooves, allow the stanchion a slight longitudinal motion, which is restrained by strong helical buffer springs, R, to be described hereafter.

On the two inner corners (toward the straining press), and raised above the main surface of the stanchion, are cast two pillow-blocks with caps *c*, while at the other corners are bolted similar pieces, *d*. The axes of their bearings are parallel to the edge of the tracks.

In the axis of the stanchion and between the outer pillow-blocks is bored a hole through which passes the rod for supporting the platform block *e*. The lower end of this rests on a screw working in a bar secured across the stanchion near its lower surface. At the inner end, near the base on either side, are the lugs *f*, which receive the lower ends of the rods on which is balanced the stationary holder. Lugs *g* cast on the top surface near the outer sides and between the pillow-blocks, form bearings for the ends of the adjusting springs of the scale platforms; while on the outer sides near the bottom are the four lugs *h* which support the spring struts for the same. On the pillow-blocks, just outside of and parallel to the main screw-bearings, are holes through which pass the drawing bolts.

THE BUFFER SPRINGS.

(R, Plate V.)

These are in duplicate, and consist of a box-like casting *a* bolted on each side of the bed-plate in a horizontal position with its axis parallel to the track. In the center is a strong partition *b*, in the middle of which is a hole for the reception of a sliding cylindrical nut *c*. Holes are also bored in the ends of the casing. In these holes enters the collars of centrally perforated disks *d*. Headed rods *e* pass through the stanchion and through these perforations, and are screwed into the nut *c*. On each of the partitions is a perforated disk *f* encircling the rods. Between the disks *d* and *f* are placed two helical springs *g*, one inside the other. The other ends of the rods are secured to the walls of the stanchion. The strength of the springs may be adjusted by set screws *h* in the end of the casing, acting against the disk *f*. Any movement of the stanchion acts against one of the rods *e* which forces the nut *c* against the disk, thereby compressing the corresponding spring.

THE SCREWS.

(E, Plate IV.)

These are in duplicate, and are forged iron 48 feet long and 8½ inches in diameter. For the greater portion of their length they are threaded with a truncated V-thread, two to the inch. At the termination of the thread they are cylindrical for a short distance, and are then enlarged so as to form a square shoulder against the outer surface of the inner pillow-block *c*, the bearing of which it fits accurately. Beyond the bearing it is again enlarged and forms a square shoulder *i*. The succeeding portion passes through the scale platforms and is again threaded for the collar nut *j* and reduced to 6 inches diameter for the bearing in the outer pillow-block, and terminates with a cup nut *k* which presses against the pillow-block.

At the other extremity of the screws the forging is turned down to pass through holes near the extremities of an eye-bar (S, Plate II) and secured by cap nuts. To this eye-bar is bolted the vertical steel spring struts (T, Plate II), the lower ends of which are bolted to the track.

The three intermediate rests (K, Plate II) (for each screw) consist of an upright portion, a bed, and a counter-weight.

The bed is of cast iron bolted to the foundation, outside of, and against the tracks, having two projecting ears, to which the upright is hinged by means of a bolt, in such a manner that it may be turned about a horizontal axis, at right angles to the track, into a horizontal position. The general form of the upright is that of a slightly ribbed flat plate, having on the upper surface a semicircular bearing to receive the screw. A forked hook fitting over and bolted to the upright clasps over the screw in order to prevent the same from springing during very heavy tensile tests. At the lower extremity of the upright is attached a mass of cast iron inclosed in a chamber beneath the floor, so that a very slight force can turn the whole system. Before depressing these the weight of the screw is taken off by means of a jack screw.

LIVE-HEAD AND SHAFT.

(U and M, Plate II.)

The live-head is bolted between the tracks and just beyond the end of the screws, and resembles an ordinary lathe-head with back-gear. It is arranged to rotate in either direction by means of a counter shaft with straight and crossed belts.

In the prolongation of, and pinned to the spindle by means of a collar, is a shaft extending nearly to the stanchion and central with the tracks. This shaft has a longitudinal rectangular groove cut along its entire length, on which slide two feathered gears for rotating the bronze nuts of the straining press.

This shaft is supported by bearings L, which are essentially rectangular rods weighted at the bottom and pivoted to plates placed in chambers between the tracks, and have a longitudinal motion in both directions. The pivoted bearing of the shaft is forked underneath and pinned to the upright portion, thereby giving support to the shaft, and being more easily moved out of the way by the guards on the straining press and movable holder. It is held in this position by a spring catch.

THE STRAINING PRESS.

(A, Plate VI.)

This is an iron casting placed on a four-wheeled truck running on the tracks. Its general shape is that of a cylinder, with one end slightly convex, and having two longitudinal semicircular offsets on opposite sides. Its cylinder is 20 inches in diameter and allowing a stroke of 24 inches. The axis is central and parallel with the track and at the same height as the middle point of the rectangular hole in the scale platform. This cylinder *a* is lined with rolled copper *b* to prevent the oil being forced into the cast iron. On the sides through the offsets are cylindrical holes, the axes of which are in the same horizontal plane as that of the cylinder, through which freely pass the screws E. The cylinder *a* is covered by its head *c* bolted in place, through which passes the 10-inch steel piston-rod *d* of the press. Resting against the cylinder head is an annular ring packing of leather *e* with upturned edges, one of which covers the junction of the cylinder and head; the other surrounds the piston-rod. For each face of the piston there are U-shaped ring packings *f* of leather.

The piston and rod are forged in one piece.

Pipes enter each end of the cylinder at the bottom, and are connected by jointed pipes, for the flexible joints of which see Plate XII, with valves in the scale case, and thence lead to the accumulator or tank. A connection is also made by jointed pipes from the top of the cylinder at either end, with pressure gauges.

The four-geared bronze nuts *g*, two on each screw, include the press between them (a slight play of about two-hundredths of an inch is given between them and the press). The nuts *g* are made to rotate in unison by gearing into intermediate gears *h* attached to the truck J, which connect with those on the live-head shaft M. In testing weak samples which have great elongation (as small ropes) the strain may sometimes be more conveniently applied by moving the press by means of these nuts rather than by forcing in the piston. The nuts when at rest serve to hold the press in place.

THE STATIONARY HOLDER.

(F, Plate VII.)

This is balanced on two vertical steel rods and steadied by two horizontal rods resting in slight depressions in the holder and pillow block. It consists essentially of three heavy masses of cast iron *a b c* having vertical holes at the four corners, through which pass the tie-rods *d*. The lower piece *c* is secured by nuts. The upper one *a* rests on a shoulder on the rods *d* and is secured by similar nuts. The middle piece slides on the rods.

The blocks *a b* have a projection (towards the scale platforms) from the rear portion of the mass and are secured by two 4-inch and one 6-inch vertical steel pins to the link.

On the under surface of block *b* are bored two 14-inch cylindrical holes *e*, and directly below these and fitted to them are cylindrical brass cups *f* attached to the lower block. These cups have a leather packing *g* and with the holes *e* form the hydraulic press for forcing the middle block against the sample placed between it and the upper block. Tubes lead from these rams to the exterior, whence pipes connect with the valves in the holder-gauge case and thence to the tank or accumulator.

The face of the projection of blocks *a b* is planed so as to bear evenly against the inner scale platform, and is provided with a low flange *h* at bottom of *b* and top of *a*.

THE MOVABLE HOLDER.

This is mounted on a four-wheel truck running on the track. In construction it is almost identical with that of the stationary holder. The face of the projections toward the straining press is slightly rounded and is connected by three similar pins to the fork which is screwed on the piston rod of the press. The pipes connecting with the valves in the holder gauge case are jointed.

THE SCALE PLATFORMS.

(B, Plate IV.)

These are two thick plates of cast iron, B, the general shape of which is that of a rectangle with rounded ends. Through these plates and on the horizontal plane that divides them symmetrically are holes through which the main screws pass without contact. In the middle is a rectangular hole for the passage of the link. Offsets are on these platforms on their upper and lower surfaces near their inner surfaces for the pressure springs. Low flanges, *m*, are formed near the outer surfaces which serve together with the grooved plates *n* and similar flanges to connect the inner platform with the stationary holder, or the outer with the platform block.

Between the platforms and to the inner one are screwed eight stop blocks, *o*, of cast iron about .02 inch shorter than the space occupied by the supports *p* in their initial condition. These serve to hold the supports in place, and receive the strain in case of injury to one of the same. Between the platforms, and near both upper and lower edges, are secured (one to each platform) the middle of two horizontal flat springs, *q*. The ends are drawn together by bolts. Just outside the holes for the main screws on each side are screwed to each platform one of the ends of vertical flat springs *r*. The other ends which extend nearly to the bed-plate are drawn together by bolts. These eight springs tend to draw the platforms together so that an initial pressure of about 16,000 pounds acts on the supports.

On the outer surface at the bottom of one platform is screwed a horizontal flat "adjusting spring." The other extremity passes through the lugs *g*, where it is secured by nuts on each side of the same. The other platform has a similar spring, which is reversed in position and connected with the lug on the opposite side of the stanchion. These springs with their nuts serve to bring the platform system exactly at right angles horizontally with the line of strain. To the outer edges on each side (at the height of the screw axis) of each platform are screwed vertical steel-spring struts, passing through lugs *n*, and provided with two nuts inclosing the same. These four spring struts serve to support the platforms and to adjust their height, and place the faces in a vertical plane.

Passing through the holes in the pillow-blocks and screwed into the outer surface of each are rods, *s*. These are provided on the outer surface of the blocks with two metallic washers having a rubber between them and a nut. By screwing up each pair, the corresponding platform is brought against its collar nuts. The rubber allows a slight vibration.

THE PLATFORM BLOCK.

(*e*, Plate IV.)

This is a casting having a square planed face where it comes in contact with the outer platform. For a short distance the sides are parallel, and then converge. A fork is cut in the rear portion. Extending from this through to the face is a rectangular opening similar to that in the scale platforms for the passage of the link. Parallel to the face near the rear portion is a vertical hole which receives a 7-inch steel pin, and secures one end of the link. The block is secured to the outer scale platform by the flange and plates already described. It is balanced on the rod *t*.

All the pins for securing are of chrome steel.

THE LINK.

(*c*, Plate IV.)

This is a steel forging having a fork at one end, both prongs of which are pierced with three holes, through which pass the stationary holder pins. Near the other end is the hole by means of which it is connected with the platform block by the 7-inch pin. The thickness of the link is reduced when it passes through the scale platforms. In testing tensile samples when the stationary holder has been removed, the link is centered by means of two rods, *u* (one each side), one end of which rests in a depression on the side of the link near the junction of the fork, the other in a similar support on the inner surface of the inner pillow block.

THE SCALE SUPPORTS.

(Plate VIII.)

These are four in number, and consist of a cylindrical casing, *a*, having on the exterior two lugs, *b*, for the purpose of holding the support to the stops. A rectangular circular groove is cut on the top surface. This is secured to the base *d* by sixteen screws, *e*. The base is centered to the ring by a raised edge on the former. Near the outer edge on the top surface of the base, but covered by the ring *a*, when in position, is a circular groove, *f*, nearly rectangular in cross section. On the same face are cut six shallow circular grooves, *g*. Commencing with the inner groove is a radial groove, *h*, at the extremity of which is a cylindrical cavity filled by the cylinder *i*. Concentric with the case *a* is the piston *k*, on the under surface of which are cut four shallow circular grooves. The piston is retained in its central position, and yet allowed a slight longitudinal motion by means of a fixing diaphragm, *m*, which is essentially a circular trough (of thin brass), the upturned edges of which enter the grooves *c* and *n* of the case and of the piston near its head, where they are secured by lead caulking. A countersunk ring, *o*, incloses the head of the piston and rests on the shoulder, but does not touch the case. The top of the piston is on a line with the bottom of the countersink, in which is fitted a disk of rubber, *p*, thicker than the same.

Two disks of brass (five thousandths of an inch thick) with upturned edges, one fitting closely inside the other, are placed with the flat surfaces in contact, and the edges (turned in the same direction) are inserted into the groove *f*, which groove is filled with solder. The lower disk is perforated by a small hole, and at this point secured to the perforated cylinder *i*, through which a right angled aperture passes. These disks thus form a sealed (except at the aperture) chamber fifteen one thousandths of an inch deep between the piston and base. A perforated plug *q*, is screwed into the block *i*, and this in turn receives the screw-plug *r*, to which the copper transmitting tube is attached. These tubes are about eighteen hundredths of an inch in diameter, and have a bore of about one tenth of an inch. The passage formed by the radial groove *h* is continued by grooves on the outside of the block *i*, and plug *q*, to the exterior of the support.

After the support has been assembled, the space between the two diaphragms is filled, as far as possible, with a mixture of alcohol and glycerine, then placed between the jaws of one of the holders. To the screw-plug *q*, is connected a larger pipe containing the same mixture, which in turn is connected with the supply pipe of the holder, and a measured pressure brought to bear on the liquid, while the piston is prevented from rising by the pressure of the holder. This forces the diaphragms into the grooves, brings them to a bearing, and fills the space with the liquid. Any air that may be between the lining diaphragm and the base, is forced out through the radial groove. In connecting the supports with the smaller supports, great care is taken to exclude any air bubbles. When in position, the base of the support rests against the inner platform, and the rubber ring against the outer.

THE SCALE.

(Plates IX, X.)

This may be best considered under two divisions: the receiving and transmitting portion, Plate IX, and the scale proper, Plate X.

This portion (Plate IX) consists of the frame *a*, and the fulcrum block *b*. Four small supports *e*, two pressure blocks *f*, two levers *g*, the receiving block *h*, and the transmitting rod *i*.

The frame *a* is a cast-iron block, to each end of which is notched and screwed the fulcrum-blocks *b*. The lower ends of the frame-struts *c* are screwed to this casting, as is also block *d*, to which is fastened the steadying-spring *l*.

The small supports, Plate VIII, consist of a base block *d'* mortised into the frame and secured by a screw. A circular chamber is cut in the upper surface, which serves to center the case, to which it is fastened by screws. Near the inner edge of this chamber is a circular groove, *f'*, filled with lead. Inside these grooves, on the upper face, is turned a shallow hole. Covering this chamber, and resting on the lead, is a disk of thin tempered steel *h'*. This is secured by the case being screwed down on the base. From the chamber *g'* a hole is bored, which meets the portion tapped to receive the perforated screw-plug *r'*. The piston *k'* rests on the steel diaphragm, and is held in position by the fixing diaphragms *m'*, as in the large supports.

The pressure block *f*, Plate IX, rests on the piston, and is held in position by means of a steel plate *l*, screwed to the block *d*, and to pieces projecting below the base of the block and fastened to the same.

This block rests on two of the small supports. Connected with this block, and directly above its center, is a vertical steel plate *m* about three hundredths of an inch thick, and forced into a groove about eight hundredths of an inch deep. This plate extends the whole length of the block, and its upper edges are forced into a similar groove in the lever *g*. The fulcrum and fulcrum-block are attached in a similar manner. The inner ends of the levers *g* are notched into each other, and along the center line of this notch is fixed a plate of thin steel, connecting with the receiving block *n*. To this block is notched and screwed the head *k* of the transmitting bar, which passes through a cylindrical opening to the weighing beam. Holes are bored in the levers *g* for the passage of the struts *c* whose upper ends are doweled into the scale-frame casting. This method of using thin plates for flexible joints, and lever bearings is general, both for the scale and gauges; thus avoiding friction and changes of position. The steel plates vary from five thousandths of an inch to three hundredths of an inch in thickness. In the case of thin plates they are generally clamped instead of being forced into grooves cut in the solid block.

THE SCALE PROPER.

(Plate X.)

The transmitting rod presses directly against a block which is connected with the main beam *a* in a manner similar to that of the pressure block *f* and lever *g* (Plate 9), to the fulcrum attachment, except that the steel plates are clamped. This beam is a strong iron casting balanced by counter weights, one of which, *b*, is removable. The motion of the further end of this beam is restrained by set screws *c*. Directly above this beam is placed the indicator beam *d*, connected with the former by two steel strips. The latter beam is suspended in a similar manner between the connection with the main beam and the free (or pointer) end. Directly behind this pointer is fixed to the frame a graduated plate *e* with zero at the center over which the pointer stands when the scale is balanced. This beam *d* is a light balanced rod, braced for the greater part of its length by adjustable steel rods, suspended freely by steel strips. From the main beam are vertical cylindrical poise rods *f* which extend without contact a short distance below the bed of the scale. The rods are provided with collars; the first three rods have ten, the last but seven collars. Parallel to, and on each side of these poise rods, are similar "carrying" rods *g* passing through the bed of the scale, and connected rigidly at their lower ends in pairs. These have collars corresponding in number to that of the included poise rods. The upper surface of the collars are joined to the cylinder by conical surfaces. These surfaces serve to center the weights. The carrying rods are raised and lowered by levers connected with the handles *h* on the left of the scale case.

Brass pieces or weights *i* of rectangular cross-section (carefully adjusted as to weight), having three holes through which the cylindrical portion of poise and carrying-rods pass freely, encircle these rods. By lowering the carrying-rods, one or more weights may be made to rest on the collars of the poise rods, and thus add to the weight of the main beam. The handles also operate vertical rods carrying pointers *k* moving over an indicator plate, *l*, thus showing the number and kind of weights added to the main beam. Thus the right hand lever *h* will weigh from 100 to 1,000 pounds by increments of 100 pounds, the second 1,000 to 10,000 pounds by increments of 1,000 pounds, the third 10,000 to 100,000 pounds by increments of 10,000 pounds, and the fourth 100,000 to 700,000 pounds by increments of 100,000 pounds.

Strains between 1 and 100 pounds are weighed by a rider, *m*, sliding on a scale fastened to the main beam to the left of the fulcrum. Should the removable weight *b*, suspended to the left of the beam, be disconnected, a pressure of 200,000 pounds on the supports would be required to balance the scale. The main beam is also provided with sliding weights *n*, to balance in part the initial pressure on the supports.

To the right of the handles *h*, are placed four hand wheels, *p*, connected with valves. From left to right their uses are as follows: The second allows the oil to pass into the pipes leading to the front end of the straining press (for tension). No. 1 allows this oil to return to the tank. No. 3 allows the oil to pass into the rear end of the straining press (for compression), and No. 4 returns the same to the tank.

The scale is protected from injury by a case with a glass front. All levers, etc., are outside. The motion of the piston in the large supports is $\frac{1}{420000}$ that of the point of the indicator beam.

THE HOLDER GAUGES.

(Plate XI.)

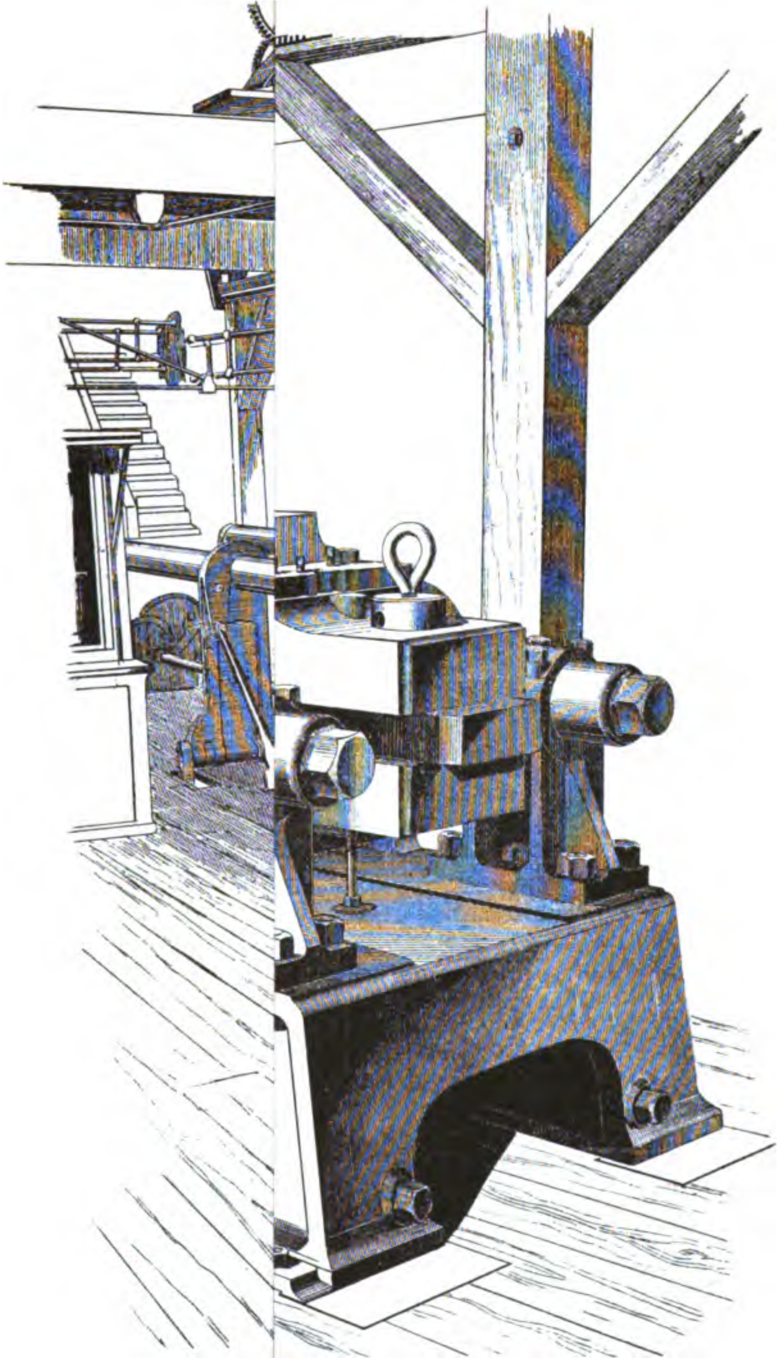
These are essentially lever gauges and receive the pressure on a diaphragm cylinder similar in construction to that of the scale supports. The motion of the pistons resting on the diaphragm is multiplied by three connected levers, also by means of a steel hair spring attached to the free end of the third lever, and passing around a drum on the indicator or pointer shaft. This shaft is provided with a light spring for the purpose of returning the needle to its proper place, when the pressure is removed. A strong spring fastened to the fulcrum block, and connected with the free end of the second lever, gives the necessary resistance to be overcome by the pressure. The pointer may be adjusted to zero, by means of a threaded rod passing through the top of the gauge housing, and connected with the second lever.

All rigid portions are nickel plated. The springs and connections are gilded. The gauges are inclosed in an iron housing with glass front. One gauge (right hand) indicates pressures on the specimen up to 1,000,000 pounds, the other only up to 345,000 pounds. The gauges differ only in the size of the chamber and the strength of the resisting springs.

The hand wheels (numbered from left to right) have the following uses; No. 3 brings the high-pressure gauge in use; No. 6 the low pressure; No. 2 lets the oil into the stationary holder. No. 4 into the movable holder; Nos. 1 and 5 relieves the pressure on the corresponding holders.

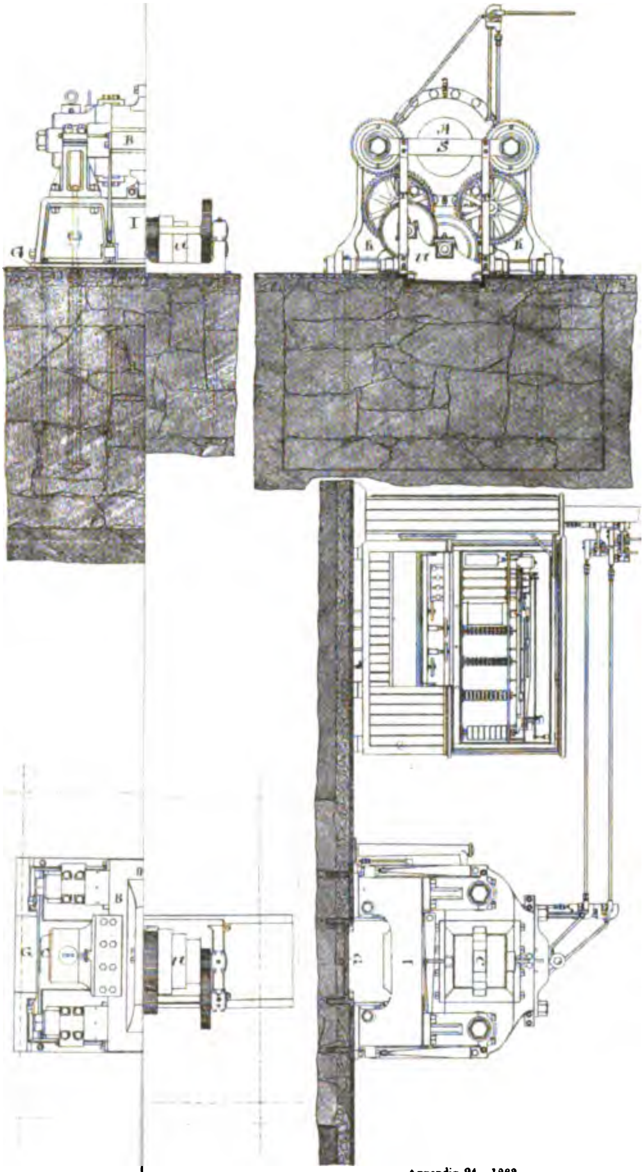
The straining-press gauges are similar in construction to the holder gauges. One for tension, the other for compression, indicating up to 850,000 pounds. These pressures are usually in excess of that indicated by the scales, owing to the packing friction.

PLATE I.



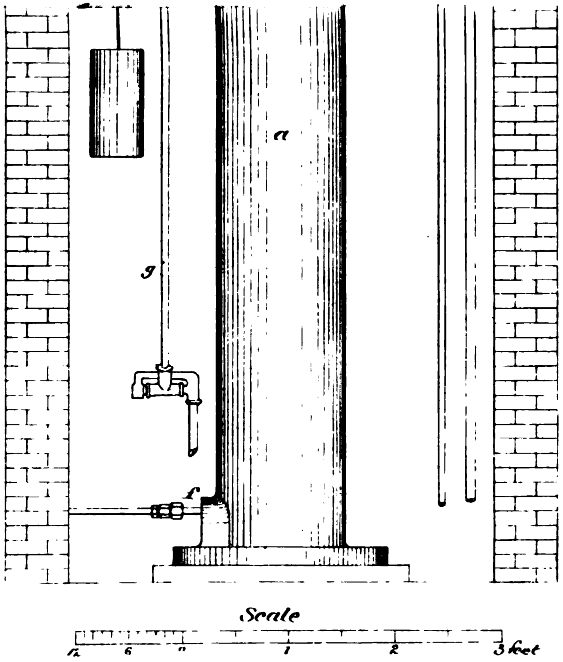
Appendix 24—1883.

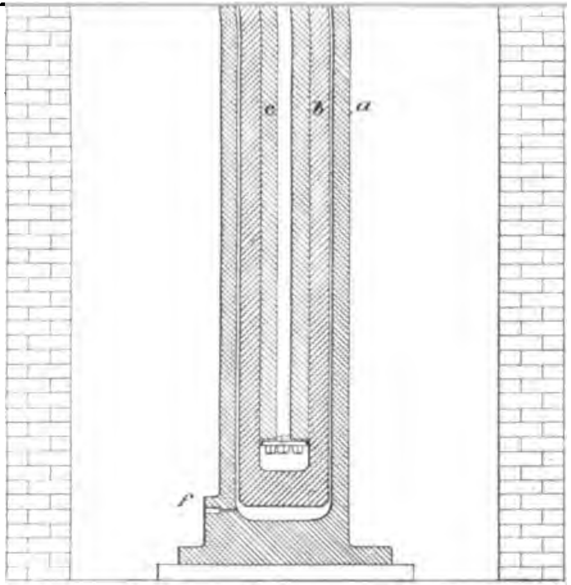
PLATE II.



Appendix 24—1883.

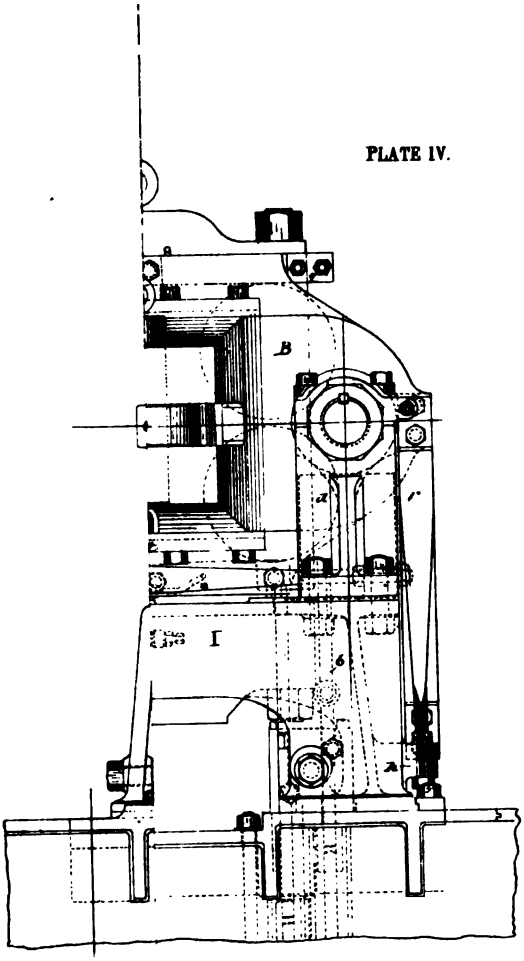
PLATE III.





Appendix 24—1883

PLATE IV.



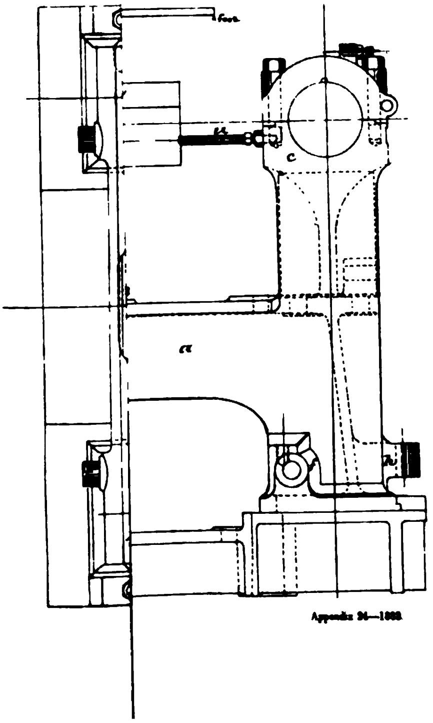


PLATE V.

Buffer Box.

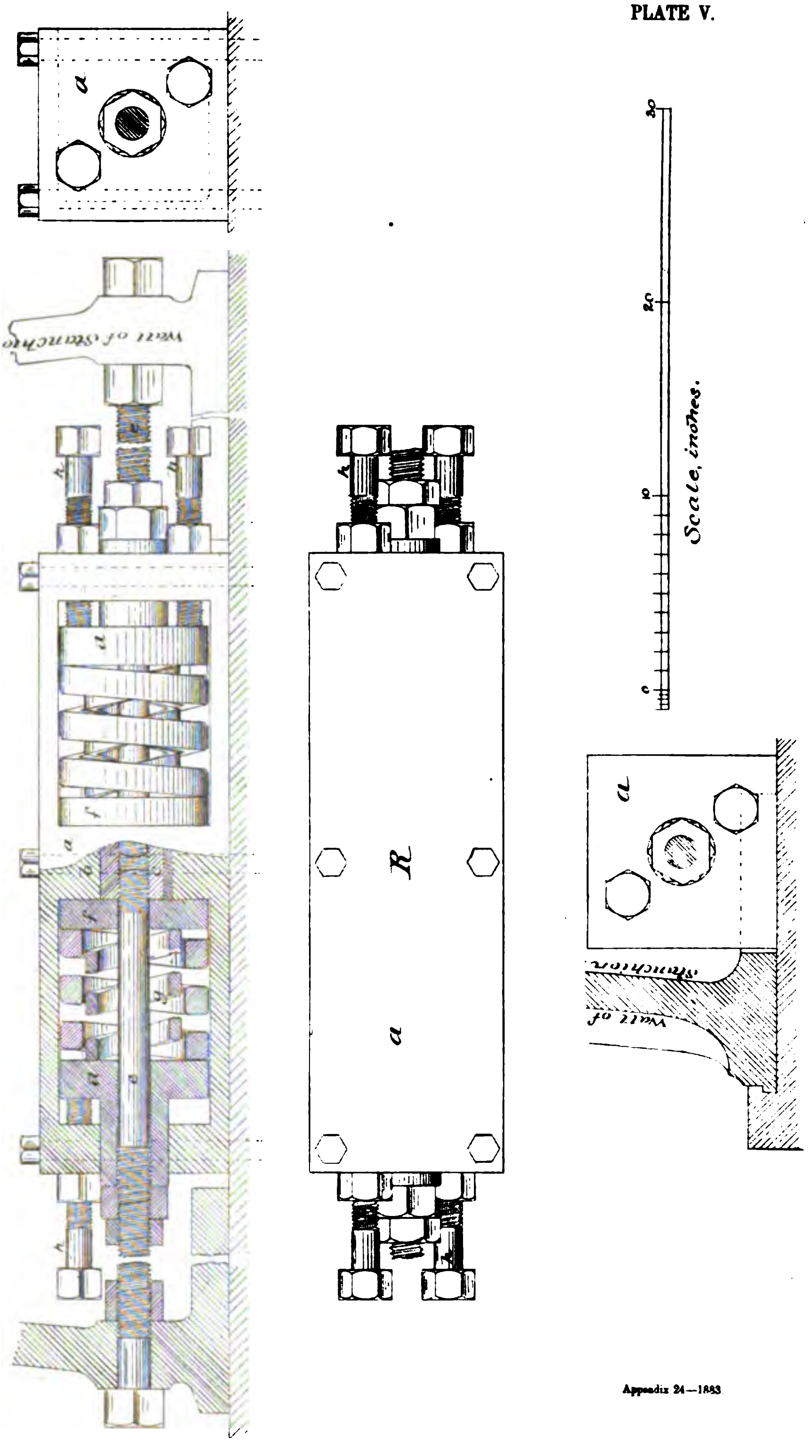
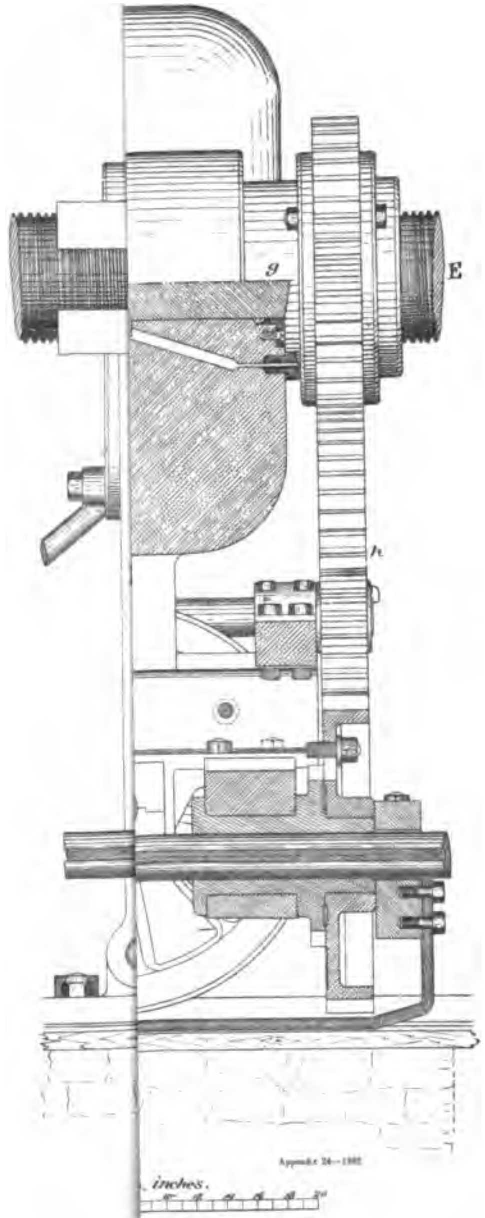
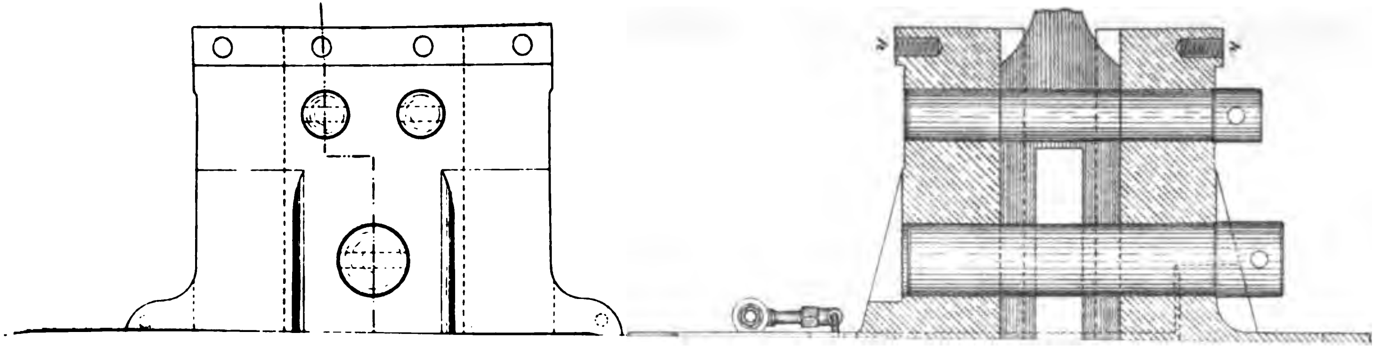


PLATE VI.

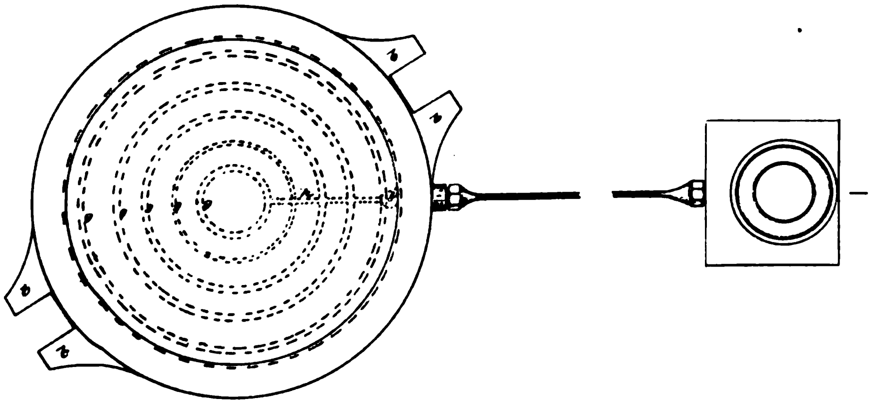


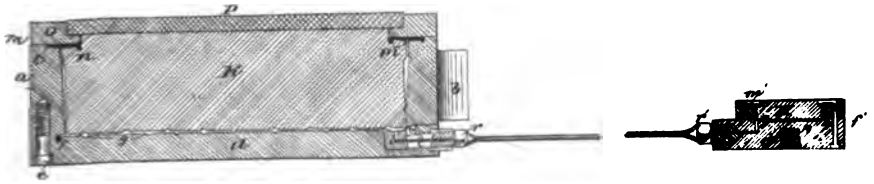
Appendix 24—1892


h
h

Scale Supports.

PLATE VIII.





Scale.

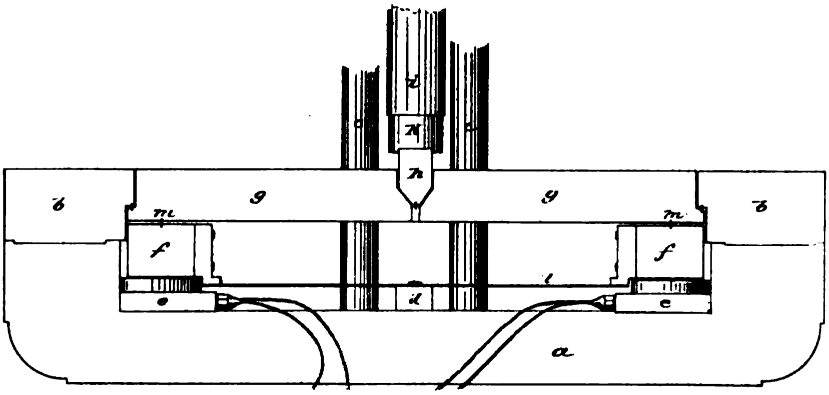
0 1 2 3 4 5 6 7 8 9 10 inches.

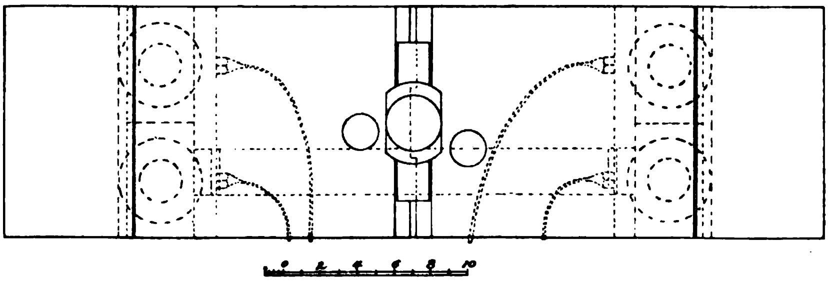
Appendix 24 - 1883.

PLATE IX.

Hydraulic Scale.

First levers.





Scale, Inches.

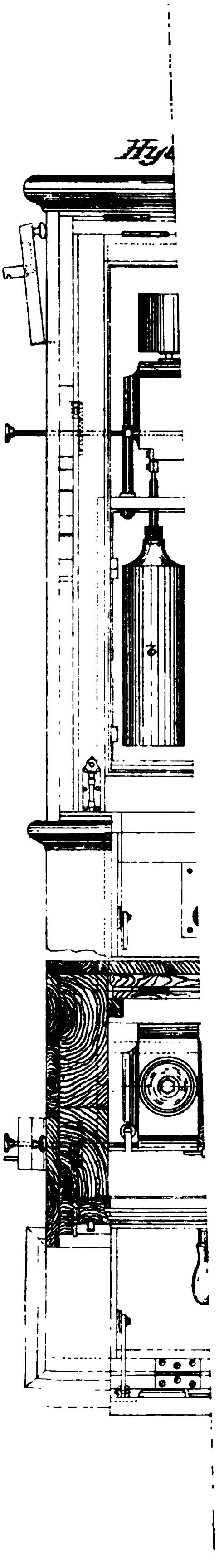

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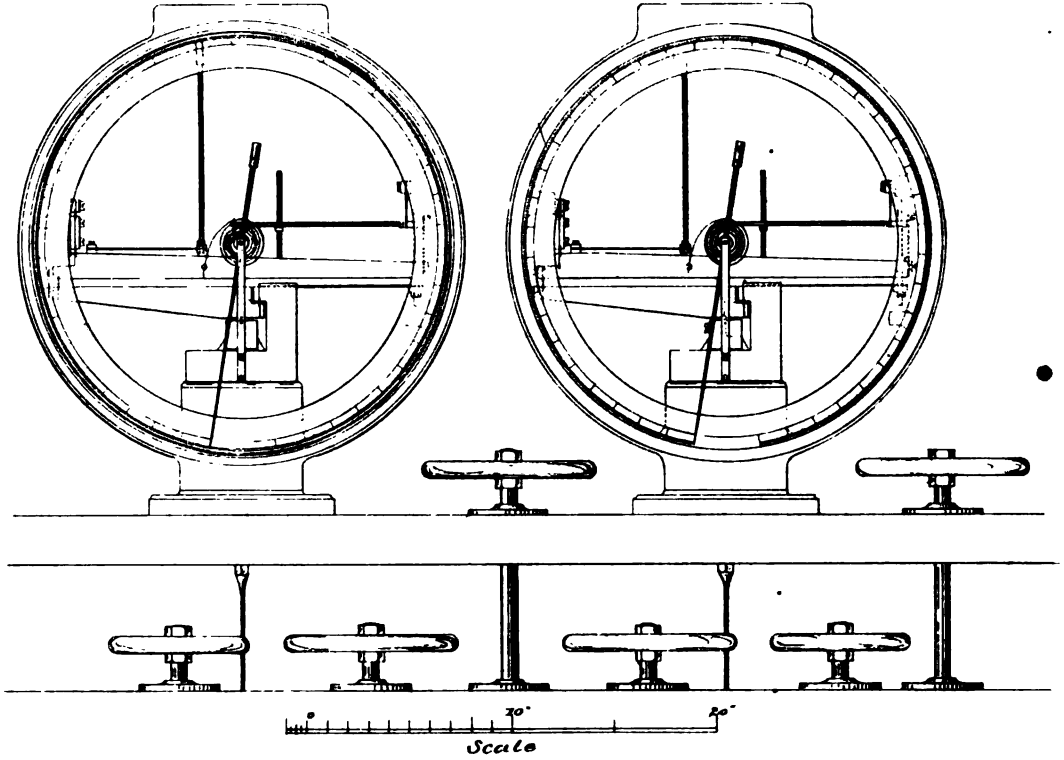
PLATE XI.

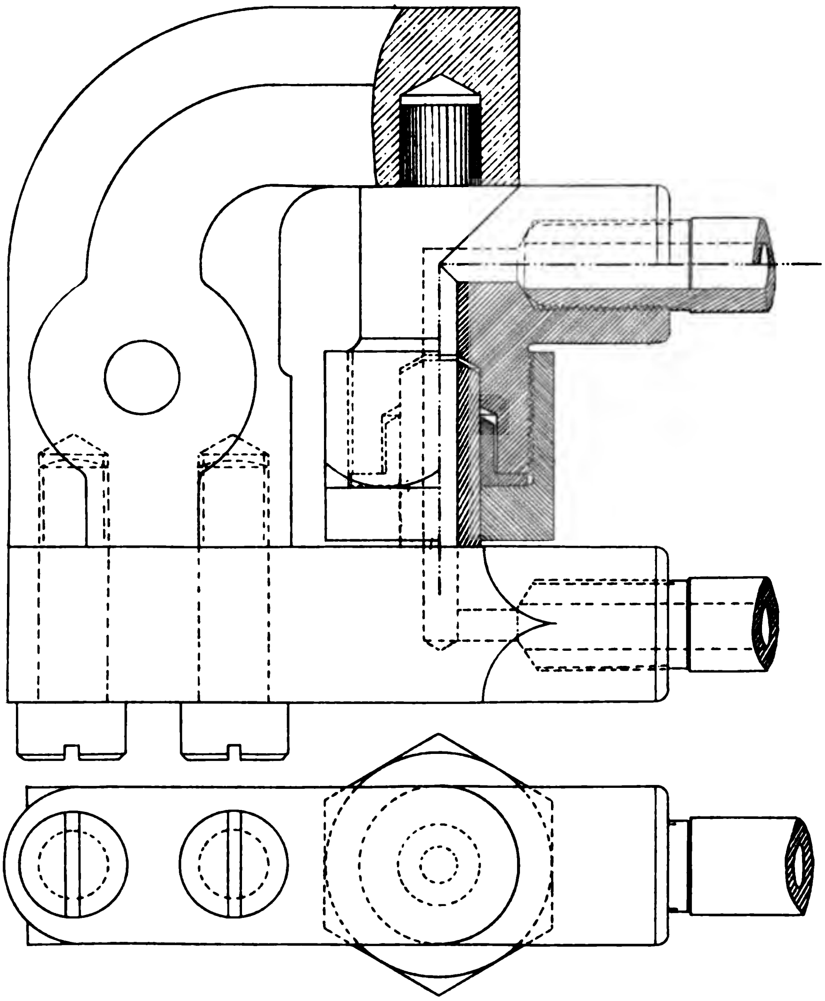
Holder Gauges



Appendix 24 - 1443

Flexible Joint.

PLATE XII.



Scale, Inches

APPENDIX 25.

TRIAL OF R. J. GATLING'S TORPEDO GUN, CALIBER 1.45 INCHES.

(4 plates.)

This gun was received at Sandy Hook, N. J., in July, 1882, and by direction of the Chief of Ordnance, dated June 29, 1882, was tried by the Ordnance Board to determine the initial velocity of the projectile, the accuracy of the piece, and the efficiency of its mechanism.

DESCRIPTION OF THE GUN.

The accompanying drawing (Plate IV) shows: Fig. 1, side elevation; Fig. 2, longitudinal vertical section through axis; Fig. 3, plan; Fig. 4, vertical cross-section, through "*x y*"; Fig. 5, front elevation; Fig. 6, rear elevation.

Component parts, lettered as on drawing: A, breech-casing, with trunnions A′; B, barrel; C, barrel-bushing; D, breech-block; E, firing-pin; F, hammer, with *f*, hammer-pin; G, mainspring; H, stirrup; I, guide-nut; J, reaction spring; K, cocking-piece; L, cocking-piece spring; M, collar on cocking-piece; N, crank; O, crank-shaft; P, gear, with *p*, rib on gear; Q, cover under breech-casing, hinge-pin *q;* R, extractor; S, bolt holding cover; T, handle cast on Q.

The gun consists of a steel barrel, B, which is screwed by its rear end into a threaded seat formed in the breech-casing A. This breech-casing is cast of gun-metal, and surrounds the barrel for some distance in front of the above thread, but is large enough not to touch the barrel except in this place. The front end of the breech-casing is closed by a bushing screwed into it and clasping the barrel (which at this point is cylindrical) in such a way that, while it holds the same firmly in its place, allows it to expand longitudinally if the barrel lengthens by heating. Behind the barrel, in a vertical seat, slides the breech-block D. In the rear of this breech-block the casing A forms a receiver, where the operator's hand can introduce a cartridge, and, when the breech-block D is in its lower position, push the cartridge directly into the chamber in the barrel. The lower front face of the breech-block D forms a rack, and the teeth of a mutilated gear, P, which is fastened on the crank-shaft O and turned by the crank N, work into this rack, and thereby alternately raise and lower the breech-block D. In the breech-block D is hung, on the pin *f*, the hammer F, which, rising with D, is swung backwards by its heel, which protrudes from the lower rear face of D, and is, by the cocking-piece K, pressed inward when D rises. When the breech-block D arrives at its highest position, and thus entirely closes the chamber in the barrel, the hammer F is released by the cocking-piece and is by the mainspring G thrown forward against the firing-pin E, which is set in D in such a manner as to be exactly in line with the center of the chamber, and therefore the cartridge is exploded when D is in its highest position. After receiving the firing blow from the hammer F, and transmitting it to the cartridge-primer, the firing-pin E is drawn back by the reaction spring J enough to clear the front face of D. The mainspring G is connected to the hammer F by the stirrup H, when, after firing, by reverse motion of crank N and gear P, the breech-block D is lowered, the heel of the hammer F engages the cocking-piece K, and entering the T-shaped slot in the latter, draws the same forward and returns to its first position, when K is drawn back by its spiral spring L. In the lower part of the rear of the barrel is set the extractor and ejector R, which is worked backward and forward by a rack formed in its lower part and the gear P. The gear, after taking down the block D, leaves the same, and continuing in the same direction, its teeth engage the rack of R, and throws R rearwards, thereby dislodging and ejecting the empty cartridge shell. On the reverse motion of the crank N and gear P the extractor is returned to its place in barrel B, and the segment rib *p* on the gear P enters a circular seat in R and prevents R from moving out of its place until the gear has pushed the breech-block D up and past R. The casing is closed by the cover Q (hinged on *q*) held by the bolt S. Cast to this cover is the handle T, by which the gun can be elevated and ranged when it is mounted and perfectly balanced on its trunnions A′. which are cast on the casing A. The crank N, making for the full action of the gun less than one-half a revolution, is stopped at both limits by a rest. The upper rest is so constructed as to stop the crank N just before the firing point is reached, giving the operator a chance to sight the gun; then a slight motion of the crank fires the shot. To strengthen the rear part of the breech-casing A, a rib which enters into the breech-block D is placed on both sides of the seat of D, preventing a lateral giving way of the sides under the shock of the explosion.

The weight of the gun is 250 pounds; of shoulder-rest, 6 pounds; of gunwale bracked, 64 pounds; of swivel, 100 pounds; of ring, 9 pounds.

The cartridge-case (2,117 grains), with primer (16 grains), weighs 2,133 grains. The charge of powder weighs 1,450 grains, or 3 ounces 10 grains troy. The steel bullet weighs 8,600 grains, and brass jacket of bullet 1,300; together weigh 9,900 grains, or 1 pound 8 ounces 300 grains troy. The total weight of cartridge is 13,483 grains, or 2 pounds 4 ounces 43 grains troy.

AMMUNITION.

The ammunition consisted of a charge of 1,450 grains of powder contained in a case, and a projectile weighing 9,900 grains, similar to the projectile numbered 1 in the report (on the first model 1.45-inch torpedo gun) made by the Board by indorsement of May 16, 1882.

VELOCITY.

The instrumental velocity, taken 50 feet from muzzle of gun, was 1,306 feet, this being a mean of the velocities obtained from three shots.

ACCURACY.

At 500 yards.

A target, 11 by 52 feet, of 1-inch spruce boards, was erected at a distance of 500 yards from the piece. The gun was mounted on a two-wheel carriage especially designed for it, and as the recoil on a wooden platform was great the wheels were clamped to the platform and the trail spiked down. Six sighting shots were fired, and then thirty shots were made directly at the target, with the following result:

	Feet.
Mean vertical deviation from center of impact	1.26
Mean horizontal deviation from center of impact	1.54
Mean deviation from center of impact	1.99

At one mile.

A target similar to the preceding one, except that its dimensions were 20 by 40 feet, was then erected at the distance of a mile from the gun, and two series of firings were carried on, with the following results:

FIRST SERIES—NINE SHOTS.

	Feet.
Mean vertical deviation from center of impact	2.31
Mean horizontal deviation from center of impact	1.47
Mean deviation from center of impact	2.74

SECOND SERIES—EIGHT SHOTS.

Mean vertical deviation from center of impact	2.47
Mean horizontal deviation from center of impact	0.97
Mean deviation from center of impact	2.65

No tests were made as to rapidity of fire on account of the instability of the carriage, which required sighting for each shot.

The shots Nos. 67 to 74, both inclusive, were made from the gun mounted on a pintle set in a stout post to simulate the arrangement of the gun when mounted upon the rail of a vessel.

The details of each shot fired and the plotted targets are inclosed herewith.

ACTION OF THE MECHANISM.

The mechanism is strong in its construction, and the working of the piece was entirely satisfactory. No difficulty was experienced in loading and firing. The piece can be readily aimed. No experiments were undertaken to test the effect of fouling the mechanism by dust or sand, as the gun presented was essentially a naval gun and designed to be used on shipboard. The carriage was not made a special subject of experiment by the Board, as the trials were carried on more with a view to testing the arrangement and action of the mechanism and the accuracy of the gun. The horizontal deviations at a mile were so small as to prove that the piece was as accurate as is necessary at that range.

The inventor, Dr. R. J. Gatling, desires that the detailed drawings and description of the torpedo gun shall not be published at present, as he has not secured foreign patents for the same.

T. G. BAYLOR,
Lieut. Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with caliber 1.45 *inches* (37 *millimeters*), *Gatling*

ONE

	Number of fire.	Time.	Powder, weight.	Projectile, weight.	Elevation.	Instrumental velocity, 50 feet from muzzle.	Direction of wind as regards line of fire.
		1882.	*Grains.*	*Grains.*	° ′	*Feet.*	
Barometer, 30.038; thermometer, 89; relative humidity, 55; wind, 6 miles.	1	July 26	1,450	9,900	....	1,314	From front and right.
	2	July 26	1,450	9,900	....	1,300	
	3	July 26	1,450	9,900	....	1,303	
arometer, 29.950; thermometer, 89; relative humidity, 50; wind, 15 miles.	4	July 27	1,450	9,900	1 00	....	From front and left.
	5	July 27	1,450	9,900	—55	....	
	6	July 27	1,450	9,900	—50	....	
	7	July 27	1,450	9,900	—50	....	
	8	July 27	1,450	9,900	—50	....	
	9	July 27	1,450	9,900	—50	....	
	10	July 27	1,450	9,900	45	....	
	11	July 27	1,450	9,900	45	....	
	12	July 27	1,450	9,900	45	....	
	13	July 27	1,450	9,900	45	....	
	14	July 27	1,450	9,900	45	....	
	15	July 27	1,450	9,900	45	....	
	16	July 27	1,450	9,900	45	....	
	17	July 27	1,450	9,900	45	....	
	18	July 27	1,450	9,900	45	....	
	19	July 27	1,450	9,900	45	....	
	20	July 27	1,450	9,900	45	....	
	21	July 27	1,450	9,900	45	....	
	22	July 27	1,450	9,900	45	....	
	23	July 27	1,450	9,900	45	....	
	24	July 27	1,450	9,900	45	....	
	25	July 27	1,450	9,900	45	....	
	26	July 27	1,450	9,900	45	....	
	27	July 27	1,450	9,900	45	....	
	28	July 27	1,460	9,900	45	....	
	29	July 27	1,450	9,900	45	....	
	30	July 27	1,450	9,900	45	....	
	31	July 27	1,450	9,900	45	....	
	32	July 27	1,450	9,900	45	....	
	33	July 27	1,450	9,900	45	....	
	34	July 27	1,450	9,900	45	....	
	35	July 27	1,450	9,900	45	....	
	36	July 27	1,450	9,900	45	....	
	37	July 27	1,450	9,900	45	....	
	38	July 27	1,450	9,900	45	....	
	39	July 27	1,450	9,900	45	....	

gun No. 2, at Sandy Hook, N. J., from July 26 to September 6, 1882.

BARREL.

Distance from center of target, in feet.				Distance from center of impact, in feet.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Vertical.		Horizontal.		Vertical.		Horizontal.		
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
Fired into sand butt for velocities.								
Fired at 500-yard target. Sighting shots								Direct hit 1' 3" right 5' above. Direct hit 2' 10" above 1' 10" left. Direct hit 1' 9" above 3" left. Direct hit 1' 10" above 1' 10" left. Direct hit 1' below 2" right. Direct hit 4" above 3" left.
0.17			0.08	0.87		0.94		Fired at 500-yard target. Target 11' × 52' made of 1" spruce boards. Time of firing 2 minutes and 1 second. Firing deliberate. Stop on gun during firing. Gun-carriage wheels clamped to platform, and spiked through trail.
.33			.42	1.03		.60		
.75			.75	1.45		.27		
.17			1.50	.87			0.48	
1.58			1.34	2.28			.32	
2.17			1.68	2.87			.66	
1.00			4.59	1.70			3.57	
.75			.43	1.45		.59		
	0.42		6.00	.28			4.98	
	.58		1.50	.12			.48	
	.75		4.09		0.05		3.07	
	1.50		.92		.80	.10		
	2.17		2.75		1.47		1.73	
	2.17		2.84		1.47		1.82	
	2.83		3.00		2.13		1.98	
	3.08		1.00		2.38	.02		
	3.42		1.00		2.72	.02		
	2.50		4.00		1.80		2.98	
	2.42		2.00		1.72		.98	
0.50		0.16		1.20		1.18		
.42		.16		1.12		1.18		
.25		.58		.95		1.60		
1.00		1.08		1.70		2.10		
	0.50	.75		.20		1.77		
	.34	1.32		.86		2.34		
	.58	1.50		.12		2.52		
	.42	2.16		.28		3.18		
	1.50	.92			0.80	1.94		
	1.83	.66			1.13	1.68		
	3.08				2.38	1.02		
9.09	30.09	9.29	39.89	18.85	18.85	23.05	23.05	Mean vertical deviation from center of impact, 1'.26. Mean horizontal deviation from center of impact, 1'.54.
21.00 ÷ 30 = 0.70		30.60 ÷ 30 = 1.02		37.70 ÷ 30 = 1.26		46.10 ÷ 30 = 1.54		Mean deviation from center of impact, 1'.99.

Record of firing with caliber 1.45 *inches* (37 *millimeters*), *Gatling gun No.* ONE

	Number of fire.	Time.	Powder, weight.	Projectile, weight.	Elevation.	Instrumental velocity, 50 feet from muzzle.	Direction of wind as regards line of fire.
		1882.	*Grains.*	*Grains.*	° ′	*Feet.*	
Barometer, 29.851; thermometer, 87; relative humidity, 61; wind, 16 miles.	40	Aug. 7	1,450	9,900	4 40	....	From front and right.
	41	Aug. 7	1,450	9,900	4 30	....	
	42	Aug. 7	1,450	9,900	4 45	....	
	43	Aug. 7	1,450	9,900	4 40	....	
	44	Aug. 7	1,450	9,900	4 45	....	
	45	Aug. 7	1,450	9,900	4 40	....	
	46	Aug. 7	1,450	9,900	4 40	....	
	47	Aug. 7	1,450	9,900	4 40	....	
	48	Aug. 7	1,450	9,900	4 40	....	
	49	Aug. 7	1,450	9,900	4 40	....	
	50	Aug. 7	1,450	9,900	4 40	....	
	51	Aug. 7	1,450	9,900	4 40	....	From right and front.
	52	Aug. 7	1,450	9,900	4 40	....	
	53	Aug. 7	1,450	9,900	4 40	....	
	54	Aug. 7	1,450	9,900	4 40	....	
Barometer, 29.718; thermometer, 85; relative humidity, 66; wind, 13 miles an hour.	55	Aug. 8	1,450	9,900	4 40	....	From front and right.
	56	Aug. 8	1,450	9,900	4 40	....	
	57	Aug. 8	1,450	9,900	4 40	....	
	58	Aug. 8	1,450	9,900	4 40	....	
	59	Aug. 8	1,450	9,900	4 40	....	
	60	Aug. 8	1,450	9,900	4 40	....	
	61	Aug. 8	1,450	9,900	4 40	....	
	62	Aug. 8	1,450	9,900	4 40	....	
	63	Aug. 8	1,450	9,900	4 40	....	
	64	Aug. 8	1,450	9,900	4 40	....	
	65	Aug. 8	1,450	9,900	4 40	....	
	66	Aug. 8	1,450	9,900	4 40	....	
Barometer, 30.119; thermometer, 79; relative humidity, 62; wind, 3 miles an hour.	67	Sept. 5	1,450	9,900	....	....	From rear and right.
	68	Sept. 5	1,450	9,900	....	....	
	69	Sept. 5	1,450	9,900	....	....	
Barometer, 30.204; thermometer, 75; relative humidity, 71; wind, 16 miles an hour.	70	Sept. 6	1,450	9,900	....	....	From front and left.
	71	Sept. 6	1,450	9,900	....	....	
	72	Sept. 6	1,450	9,900	3 30	....	
	73	Sept. 6	1,450	9,900	3 30	....	
	74	Sept. 6	1,450	9,900	3 30	....	

2, *at Sandy Hook, N. J., &c.*——Continued.

BARREL.

Distance from center of target, in feet.				Distance from center of impact, in feet.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Vertical.		Horizontal.		Vertical.		Horizontal.		
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
Fired at mile target. Sighting shots								Struck 50 yards short. Struck 10 feet short. Left of target and beyond. Direct hit 6' left 5' below. Direct hit 9' 10½" above 5' 2" right.
....	2.95	5.92	....	....	0.65	2.14	....	Fired at mile target. Target 20' × 40', made of 1" spruce boards. Firing deliberate. Stop on gun during firing. Gun secured by bolt in trail, and by chocks in front, rear, and on sides of wheels.
....	....	2.68	....	2.30	....	....	1.10	
4.00	....	4.25	....	6.30	....	.47	....	
....	2.75	5.84	....	....	.45	2.06	....	
....	9.50	5.50	....	....	7.20	1.72	....	
....	.50	3.00	....	1.80	....	....	.78	
....	3.00	....	0.75	....	.70	....	4.53	
....	3.00	3.58	....	....	.70	....	.20	
Under target...		....	....	....	....	....	....	
....	3.00	4.00	....	....	.70	.22	....	
4.00	24.70	34.77	0.75	10.40	10.40	6.61	6.61	Mean vertical deviation from center of impact, 2'.31. Mean horizontal deviation from center of impact, 1'.47. Mean deviation from center of impact, 2'.74.
20.70 + 9 = 2.30		34.02 + 9 = 3.78		20.80 + 9 = 2.31		13.22 + 9 = 1.47		
Fired at mile target. Sighting shots.								Direct hit 14' 10" left 4' above. Missed.
....	4.42	....	14.50	....	7.90	1.24	....	Fired at mile target. Target 20' × 40', made of 1" spruce boards. Time of firing 3 minutes and 31 seconds. Firing deliberate. Stop on gun during firing.
1.50	....	....	15.02	....	1.98	.72	....	
3.67	....	....	15.75	0.19	....	....	0.01	
3.75	....	....	14.82	.27	....	.92	....	
5.50	....	....	14.82	2.02	....	.92	....	
4.00	....	....	15.67	.52	....	.07	....	
4.50	....	....	17.67	1.02	....	....	1.93	
9.34	....	....	17.67	5.86	....	....	1.93	
....	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	Gun secured by bolt in trail, and by chocks in front, rear, and on sides of wheels.
32.26	4.42	....	125.92	9.88	9.88	3.87	3.87	Mean vertical deviation from center of impact, 2'.47. Mean horizontal deviation from center of impact, 0'.97. Mean deviation from center of impact, 2'.65.
27.84 + 8 = 3.48		125.92 + 8 = 15.74		19.76 + 8 = 2.47		7.74 + 8 = 0.97		
Fired into sand butt.								
Fired over water								Time of flight, 4¾ seconds. Time of flight, 5 seconds. Time of flight, 5¼ seconds.

For the Board.

T. G. BAYLOR,
Lieutenant-Colonel of Ordnance, President of the Board.

PLATE I.

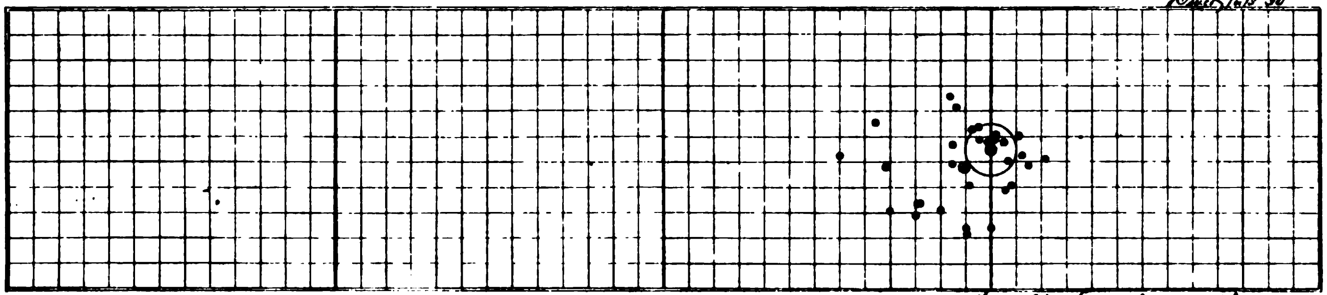
TARGET RECORD OF Calibre .45 ([illegible]) Gatling Gun No 2. (new barrel)

July 27/82 AT SANDY HOOK, N. J.

Target .... 500 yards .... *from Gun.*

Number of shots fired: 30 ..

Direct hits 30



Target 11' × 58'. Squares of 1' [illegible]

● Centre of Impact

● Point aimed at

Mean vertical deviation from centre of impact, 1.76
Mean horizontal deviation from centre of impact, 1.58
Mean deviation from centre of impact 1.99

Wind 15 *miles per hour.*

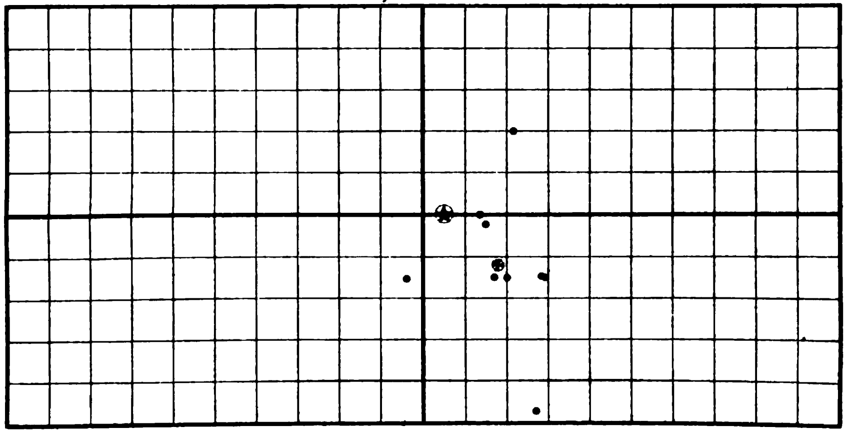
PLATE II.

TARGET RECORD of Calib. .45 (Std.) Gatling Gun No. (One barrel)

August 7/82 AT SANDY HOOK, N. J.

Target One hundred *from Gun.*

Number of shots fired, 10 . *Direct hits,* 9 . *Ricochet hits,* 0 . *Misses,* 1 .



Mean vertical deviation from centre of impact, 2.31.

Mean horizontal deviation from centre of impact, 1.47.

Mean deviation from centre of impact, 2.74.

⊛ *Centre of Impact.*

⊛ *Point aimed at.*

Target 20'× 40' made of 1" pine boards

Wind 16 *miles per hour*

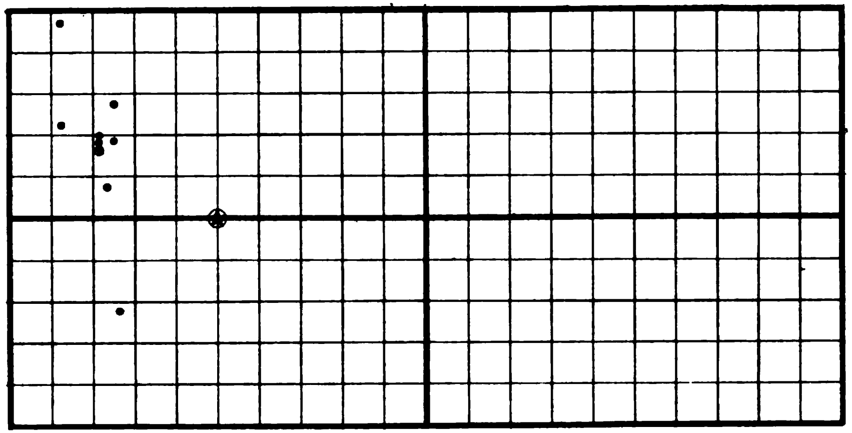
PLATE III.

TARGET RECORD of Calibre .45 (.37 %) Gatling Gun No 2 (One Hand)

August 8/82 AT SANDY HOOK, N. J.

Target One Mile *from Gun.*

Number of shots fired, 10 . *Direct hits,* 8 . *Ricochet hits,* 0 . *Misses,* 2 .



⊛ *Centre of Impact.*

⊛ *Point aimed at.*

Mean vertical deviation from centre of impact, 2.47.

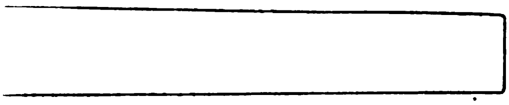
Mean horizontal deviation from centre of impact, .91.

Mean deviation from centre of impact, 2.65.

Target 20' x 40' [illegible]

Wind 13 *miles per hour.*

PLATE IV.

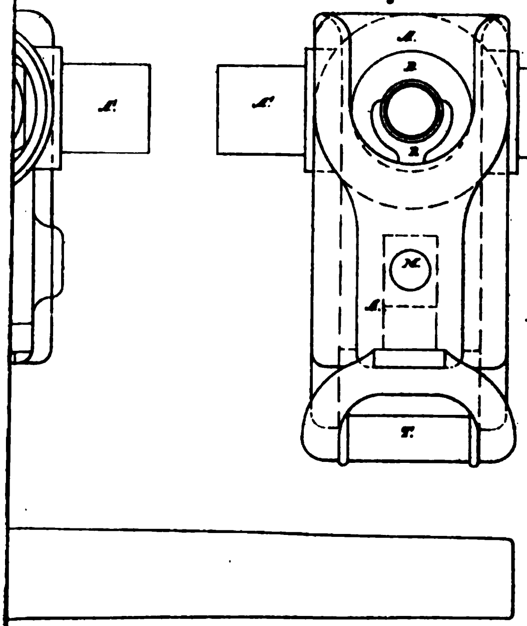


J. GATLING's TORPEDO_GUN.

CAL: 1.45 in – 37 m.

Oct. 1881.

Fig. 6.



APPENDIX 26.

TRIAL OF A NEW MAGAZINE FEED FOR THE GATLING GUN, CAL. .45 ARRANGED FOR THE BOTTLE-SHAPED CARTRIDGE.[*]

(4 plates.)

This gun was tried at Sandy Hook during the months of July, August, and September, 1882, in accordance with the directions of the Chief of Ordnance, dated June 29, 1882.

The report of the Board on the gun with this new feed "magazine" has been delayed awaiting drawings and description of the gun and carriage, which were applied for some time ago, but these details not having been furnished, the Board submits this report without further delay.

GENERAL DESCRIPTION.

The gun is, in its general features, like the 10-barrel Gatling gun, as described in the Report of the Chief of Ordnance for 1880, pages 137 and 138. It was especially made to use the English bottle-shaped cartridge and also for this new feed "magazine."

The carriage was especially arranged to fire at high angles, admitting of an elevation of 68° without sinking the trail.

EXPERIMENTS.

The object of the experiments were two-fold: First. To test the new feed "magazine." Second. To ascertain the effect on targets placed horizontally on the ground at distances from 200 to 3,000 yards, as regards penetration and accuracy.

DESCRIPTION OF THE NEW FEED MAGAZINE FOR THE GATLING GUN.

Fig. 1 is a side view of the magazine or feed case.

Fig. 2 is a view of the lower edge of the same, showing the outlet of the case.

Fig. 3 is a side view of a part of the breech of a Gatling gun, showing the feed case in position for use.

Fig. 4 is a view of the inner side of one of the side plates, showing the spiral grooves.

Fig. 5 is a detailed view of the propeller and carrier—the latter in section.

Fig. 6 is a view in longitudinal vertical section of a part of the carrier and the feed case, the plane of the section being on the axis of the gun.

The object of this improved feed magazine is to supply cartridges to the gun by positive action, not dependent on gravitation or springs. The cartridges are fed in succession into compartments in the revolving carrier or receiver, and are thrust forward from these compartments into the barrels of the gun with which they communicate.

---

[*] This title was furnished by the Gatling Gun Company after the report was written out.

In the accompanying drawings the letter *a* denotes the feed magazine as a whole, consisting of circular metal plates, *b c*, connected centrally by a hollow cylinder, *d*, and at such a distance apart that the cartridges *e* can lie and move lengthwise between the two side plates.

The plates are inclosed around their periphery except at the under side where there is an opening, *f*, for the delivery of the cartridges.

The feed magazine *a* is placed with its axis parallel to the barrels of the gun *g*, the projections, *a′ a′*, being arranged to enter corresponding recesses, *h′ h′*, in the hopper *h*, which is mounted upon the gun immediately over the carrier *i* (Fig. 6). The side plates *b c* are provided on the inside with inwardly projecting guide ribs similarly arranged opposite to each other so as to form spiral paths or guides for the cartridge, the nose of which lies between the spiral ribs on one plate and the bare flange between the spiral ribs on the opposite plate.

It is not necessary that the ribs should be formed in a true spiral curve, and it is indeed preferred that the guide ribs should be arranged in a series of concentric and nearly complete circles connected by short inclines so as to form a continuous guide track, beginning near the central cylinder *d* and terminating at the circumfernnce of the "magazine" at the opening *f*. The cartridges lying in the spiral guides are controlled by a propeller, *K*, which forms the cartridge-moving part of the feeder. The propeller consists of a hub, *h*, surrounding the central cylinder and arranged to revolve freely upon it, and of any desirable number—generally two—of parallel disks, *m*, fixed to the hub at such distance apart as to allow the whole to revolve freely between the edges of the guide flanges within the feeders. The disks are of a diameter a little less than that of the side plates of the feeder frame.

Radial slots, *n*, are cut in the propeller disks and the main portion of the cartidges in the feeder are contained in these slots, the noses and bases of the cartridges being in the guides between the spiral flanges. When the propeller is rotated to feed the cartridges out, it carries them along the spiral guides and brings them in succession to the opening *f* in the periphery where the guide terminates, and delivers them into the hopper.

The propeller is rotated by means of lateral projections or teeth, *p*, which are in mesh with corresponding teeth, *g*, on the receiver. When delivered into the hopper the cartridges pass along inclined guides, *r* (Fig. 4), which are in continuation of the feeder guides and are carried into the compartments *s* of the receiver as each compartment in succession comes uppermost. The guides in the hopper are formed by flanges which project downward into peripheral grooves cut in the receiver to about the depth of the cartridge compartments. These flanges, *t*, are convex on the upper edge t′ and concave on the lower t″, where at a suitable point they form a plow or ejector for the empty cartridges which are thrown out successively as the receiver is revolved as by the ordinary mechanism.

In order to get the cartridges into the "magazine" they are each one placed in the opening *f* (the bullets of course pointing in one direction with the axis of the feeder) and the propeller turned so as to carry the cartridges along the guides towards the central cylinder and the inner terminus of the spiral groove.

To use the device on the gun, the loaded feeder is placed upon the hopper, the projections fitting into the mortices and the teeth of the propeller and receiver intermeshed. Then upon revolving the receiver the cartridges are forced out along the guides and into the receiver compartments by the revolving propeller.

This feeding motion is positive and continuous as long as the gun is worked, and forms the main feature of the invention.

ACTION OF THE MECHANISM.

The action is, as claimed in the inventor's description, "positive and continuous as long as the gun is worked." The substitution of a positive action for one depending upon the carriage of the projectiles to the grooves of the carrier block by means of gravitation modified by friction is a great improvement. The gun works as well when the feed "magazine" is horizontal as it does in an inclined or a vertical position. No jamming or interference of any kind occurred during the trials, and the rate of discharge varied uniformly with the rate of revolution of the crank necessarily.

AMMUNITION.

The ammunition used was the English bottle-shaped cartridge, containing a charge of 85 grains of powder and a projectile weighing 480 grains, made by the Union Metallic Cartridge Company in this country. One hundred and sixty rounds were fired with a 410-grain bullet, but no results were obtained with them.

ACCURACY AT 500 YARDS RANGE.

Guns resembling the one now in question have been tried so often for accuracy that it was deemed necessary to try this one only at an ordinary range to ascertain if it was equal to those heretofore experimented with. The target obtained is inclosed herewith.

PENETRATION.

The penetration from 3,000 down to 1,000 yards was through 2 inches of spruce plank and from 3 to 5 inches into the sand, the projectiles striking point foremost. At 500 and 200 yards the projectiles were found to have struck butt first or sidewise. The penetrations under the circumstances were from one-eighth to three-fourths of an inch, the majority of them being of the former depth.

RAPIDITY OF FIRE.

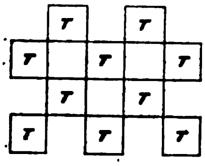
When fired by an expert, for rapidity, 104 shots were delivered in 3½ seconds. The gun was again fired to test the time in which a change of the feed "magazine" could be made. A full "magazine" was fired, removed when empty, a new-filled "magazine" was put in position and fired, making a total of 207 rounds fired with one change of case in 10¼ seconds.

ACCURACY UNDER HIGH ANGLES.

The inventor desired that a series of firings should be conducted at high angles with a view to substituting the gun with the new feed "magazine," for the mortars which are ordinarily used for high angle firing. His idea was that if an accurate vertical fire could be obtained with this piece a storm of bullets descending under a slight angle of arrival would, by grazing the superior crest of parallels erected by besiegers approaching a fortification, or those of ordinary lines of rifle pits, destroy their occupants much more certainly and rapidly than can be done by the shells or case shot fired from mortars.

Since there has been but little accurate experiment in firing small projectiles at high velocities under high angles, everything relating to the subject had to be tentative in its nature.

Ten targets of spruce boards 16 feet square were arranged in the order shown in the marginal sketch. They were laid horizontally; those in the first and second rows were one inch, those in the third and fourth rows were two inches thick.



Firings commenced at angles first of 70° then of 80°, but all attempts to find the position of the projectiles after their fall were unsuccessful. It was then determined to fire the gun under angles of about 27°, which it was believed from experiments previously made by Captain Greer would give ranges of about 3,000 yards. The targets having been established at this distance, observers were stationed near them in a sheltered position.

On July 28 eleven volleys of shots were then fired under the following circumstances:

No. of shots fired.	Elevation. ° '	Gun aimed.	Position of shots as found.
10	27	75 yards to right..	75 yards right.
10	27	At center..........	30 yards short; 50 yards right.
10	27 5	5 feet to left	Do.
10	27 10	Left side...........	One hit on right target; rest to right.
10	27 10	70 yards left	Not found.
10	27 10	50 yards left........	Do.
10	27 5	.......do	60 to 112 yards beyond.
10	27	.......do	10 yards left and beyond.
10	26 55	40 yards left	Left and beyond.
10	26 50	30 yards left	Beyond.
20	26 40	......do	Not found.
Total, 120			

On July 29 sixteen volleys were fired as follows:

No. of shots fired.	Elevation. ° '	Gun aimed.	Position of shots as found.
10	27 5	20 yards to left of center:	100 yards beyond.
10	27		75 yards beyond.
10	26 50		70 yards beyond.
10	26 45		Do.
10	26 30		Do.
10	26 15		Do.
10	26		Do.
10	25 30		30 yards beyond—10 yards to right.
10	25		In front and beyond—all about 10 yards right.
10	25		20 yards beyond.
10	24 45		5 or 6 feet to right.
10	24 45		All around targets.
20	24 45		Most of them beyond; 1 hit.
10	24 45		In front and beyond.
10	24 40		Beyond.
10	24 40		Do.
Total, 170			

From which it appears that out of 290 shots fired at a known distance, with reports made generally after each volley of ten shots, but two hits were made in a space of 64 by 80 feet.

The details of the firing at the other ranges are given in full in the accompanying firing record. They may be briefly summarized as follows:

Range.	No. of shots.	Number of hits.
Yards.		
2, 400	450	2
2, 000	915	6
1, 000	216	2
500	1, 275	1, and several hits.*
200	500	2, and several hits.*

*This term indicates that the projectiles were believed to have struck the interstitial spaces between the targets, but not the targets themselves.

In connection with the trial of this gun and ammunition, it was the intention to make some comparisons with the .45 caliber short-barrel American gun with special cartridges of 70 grains of powder and 500-grain bullets, but after firing a few hundred rounds with this gun the firing was discontinued, owing to breaking of cartridge cases and clogging of gun, due, it is thought, to an imperfect adjustment of gun and a weakness in the cartridge case itself. The records of this firing are also inclosed.

CONCLUSIONS.

The new feed case is all that is claimed for it and adds very considerably to the value of the gun. With regard to the efficacy of this kind of fire it must be said that the carriage on which the gun was mounted was entirely too light and unstable for great accuracy. Still it is evident that firing at such elevations must be very uncertain and difficult to make very effective, from the varying conditions of wind, &c., in the different strata of air through which the ball with its small mass passes.

Under very favorable circumstances, however, with a concentration of such guns, possibly an harassing and destructive fire might be obtained.

T. G. BAYLOR,
Lieut. Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Target record of firing with caliber 0".45 Gatling gun "American," at Sandy

	Number of fire.	Time.	Ammunition.	Elevation in degrees.	
		1882.		°	′
Barometer, 30.264; thermometer, 89; relative humidity, 45; wind, 6 miles.	1	July 26	Frankford solid-head cartridge, long; charge, 70 grains; bullet, 500 grains.	....	
	1	July 26	......do	....	
	1	July 26	......do	....	
Barometer, 29.891; thermometer, 89; relative humidity, 61; wind, 17.	8	July 27	......do	1	20
	100	July 27	......do	1	20
Barometer, 29.961; thermometer, 83; relative humidity, 67; wind, 8 miles.	10	July 29	......do	22	00
	10	July 29	......do	23	00
	10	July 29	......do	23	30
	10	July 29	......do	23	30
	10	July 29	......do	28	30
	10	July 29	......do	25	00
	10	July 29	......do	25	30
	10	July 29	......do	26	00
	20	July 29	......do	26	00
	20	July 29	......do	26	00
	125	July 31	......do	....	
	8	July 31	Lowell solid-head cartridge; charge, 70 grains; bullet, 500 grains.	....	
Barometer, 30.084; thermometer, 79; relative humidity, 65; wind, 8 miles.	10	Aug. 4	Frankford solid-head cartridge, long; charge, 70 grains; bullet, 500 grains.	64	00
	20	Aug. 4	......do	64	00
	20	Aug. 4	......do	64	00
	20	Aug. 4	......do	64	00
	20	Aug. 4	......do	64	00
	20	Aug. 4	......do	66	00
	20	Aug. 4	......do	65	00
	20	Aug. 4	......do	64	30
	20	Aug. 4	......do	64	00
	20	Aug. 4	......do	64	00
	20	Aug. 4	......do	64	00
	20	Aug. 4	......do	64	00
	8	Aug. 4	......do	64	00
	40	Aug. 4	......do	64	00
	20	Aug. 4	......do	64	00
	20	Aug. 4	......do	64	00
	20	Aug. 4	......do	64	00

It was found by trial that the copper cartridge shell could in this gun be creased or broken as desired, by the adjustment of a cam in rear giving the head of cartridge more or less play. When much play was given the shell broke in two about .4" from head, leaving remainder of shell in the chamber. With less play the shell would be deeply indented about same distance from head and entirely around its circumference.

Hook, N. J., from July 26 to August 4, 1882, short barrel No. 249.

Instrumental velocity, taken 50′ from muzzle.	Direction of wind as regards line of fire.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c., &c.	
Feet. 1,242	From front and right.		Fired into sand butt for velocities.
1,215			
1,244			
....	From front and left.	Vertical target.	Fired at 500-yard target; sighting shots.
....			Fired at 500-yard target. Number of hits on target, 51. Rounds 45 and 50 of this volley jammed, making working of mechanism of gun impossible, caused by base of cartridge shell coming off and leaving portion of shell in chamber.
....	From front and right.	Target slightly inclined from beach. Fired at 3,000-yard target.	Not found. Gun aimed 20 yards to left.
....			160 yards short. Gun aimed 20 yards to left.
....			Right of target. Gun aimed 20 yards to left.
....			Not found. Gun aimed 10 yards to left.
....			200 yards short. Gun aimed 18 yards to left.
....			10 to 20 yards short. Gun aimed 18 yards to left.
....			15 yards short. Gun aimed 18 yards to left.
....			In front and beyond target. Gun aimed 18 yards to left.
....			In front and beyond target. Gun aimed 18 yards to left.
....			All around target. Gun aimed 18 yards to left.
....			Fired out to sea to test cartridges.
....			
....	From front and left.	Target slightly inclined from beach. Fired at 2,000-yard target.	Not found. Gun aimed 150 yards to left.
....			Not found; possibly on right. Gun aimed 150 yards to left.
....			Not found. Gun aimed 160 yards to left.
....			Do.
....			Beyond. Gun aimed 180 yards to left.
....			Not found. Gun aimed 190 yards to left.
....			50 yards to right; 20 yards short. Gun aimed 190 yards to left.
....			20 yards to right; 20 yards short. Gun aimed 240 yards to left.
....			50 feet short; good line. Gun aimed 290 yards to left.
....			20 feet left. Gun aimed 290 yards to left.
....			20 feet left; 10 feet short. Gun aimed 280 yards to left.
....			20 feet left. Gun aimed 285 yards to left.
....			In front beyond and left. Gun aimed 285 yards to left.
....			Do.
....			Do.
....			Do.
....			All around target; 1 hit. Gun aimed 285 yards to left.

Target record of firing with caliber 0".45 Gatling gun, English No. 1, at Sandy

	Number of fire.	Time.	Ammunition.	Elevation.	
		1882.		° ′	
Barometer, 30.264; thermometer, 89; relative humidity, 45; wind, 6 miles.	1	July 26	English solid-head cartridge; charge, 85 grains; bullet, 480 grains.	....	
	1	July 26	......do	....	
	1	July 26	......do	....	
	1	July 26	......do	....	
	1	July 26	......do	....	
	1	July 26	......do	....	
	2	July 26	......do	....	
	6	July 26	......do	....	
	104	July 26	......do	62 00	
	60	July 26	......do	62 00	
	100	July 26	......do	80 00	
Barometer, 29.981; thermometer, 89; relative humidity, 61; wind, 17 miles.	1	July 27	......do	1 00	Vertical target.
	3	July 27	......do	1 00	
	3	July 27	......do	1 10	
	3	July 27	......do	1 15	
	3	July 27	......do	1 20	
	100	July 27	......do	1 20	
	100	July 27	......do	....	
	8	July 27	......do	70 00	
	16	July 27	......do	70 00	
Barometer, 29.981; thermometer, 87; relative humidity, 69; wind, variable in direction and velocity, from 12 to 18 miles.	20	July 28	......do	80 00	
	20	July 28	......do	80 00	
	40	July 28	......do	80 00	
	40	July 28	......do	85 00	
	40	July 28	......do	85 00	
	10	July 28	......do	27 00	Target inclined slightly from beach.
	10	July 28	......do	27 00	
	10	July 28	......do	27 05	
	10	July 28	......do	27 10	
	10	July 28	......do	27 10	
	10	July 28	......do	27 10	
	10	July 28	......do	27 05	
	10	July 28	......do	27 00	
	10	July 28	......do	26 55	
	10	July 28	......do	26 50	
	20	July 28	......do	26 40	
Barometer, 29.961; thermometer, 83; relative humidity, 67; wind, 8 miles an hour.	10	July 29	......do	27 05	
	10	July 29	......do	27 00	
	10	July 29	......do	26 50	
	10	July 29	......do	26 45	
	10	July 29	......do	26 30	
	10	July 29	......do	26 15	
	10	July 29	......do	26 00	
	10	July 29	......do	25 30	
	10	July 29	......do	25 00	
	10	July 29	......do	25 00	
	10	July 29	......do	24 45	
	10	July 29	......do	24 45	
	20	July 29	......do	24 45	
	10	July 29	......do	24 45	
	10	July 29	......do	24 40	
	10	July 29	......do	24 40	
Barometer, 30.339; thermometer, 75; relative humidity, 69; wind, 12 miles an hour.	72	July 31	......do	......	
	10	July 31	......do	34 00	
	10	July 31	......do	34 00	
	10	July 31	......do	30 00	
	10	July 31	......do	20 00	
	10	July 31	......do	22 00	
	10	July 31	......do	22 00	
	10	July 31	......do	18 00	
	20	July 31	......do	36 00	
	20	July 31	......do	40 00	
	20	July 31	......do	45 00	
	20	July 31	......do	50 00	
	20	July 31	......do	55 00	
	20	July 31	......do	50 00	

Hook, N. J., from July 26 to September 8, 1882. Short barrel with drum feed.

Instrumental velocity, taken at 50 feet from muzzle. *Feet.*	Direction of wind as regards line of fire.	Time of flight. *Secs.*	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.		
Lost	From front and right.	......	Fired into sand butt for velocities.		
Lost		......			
Lost		......			
1,185		......			
1,172		......			
1,190		......			
....	From front and left.	......	Fired over water.		
....		......			
....		......			
....		......			
....		......			
....		......	Fired at 500-yard target. Sighting shots.		
....		......			
....		......			
....		......			
....		......			
....		......	Fired at 500-yard target. Time of firing, 6 seconds. Number of hits in target, 90.		
....		......	Fired over water. Time of firing, 3¼ seconds. Fired by Mr. Accles.		
....		......	Fired up in air.		
....		......			
....	From front and right.	......	Do.		
....		......			
....		......			
....		......			
....		......			
....	From left to right.	......	Fired at 3,000-yard targets.	75 yards to right. Gun aimed 75 yards to right.	
....		......		30 yards short; 50 yards right. Gun aimed at center target.	
....		......		30 yards short; 50 yards right. Gun aimed 5 feet left of center.	
....		......		One hit on right target; rest to right. Gun aimed on left of targets.	
....		......		Not found. Gun aimed 70 yards left of targets.	
....		......		Not found. Gun aimed 50 yards left of targets.	
....	From rear and left.	......		60 to 112 yards beyond target. Gun aimed 50 yards left of targets.	
....		......		10 yards to left and beyond. Gun aimed 50 yards left of targets.	
....		......		Left and beyond. Gun aimed 40 yards left of targets.	
....		......		Beyond. Gun aimed 30 yards left of targets.	
....		......		Not found. Gun aimed 30 yards left of targets.	
....	From right to left.	......		100 yards beyond.	Gun aimed 20 yards to left of center.
....		......		75 yards beyond.	
....		......		70 yards beyond.	
....		......		Do.	
....		......		Do.	
....		......		Do.	
....		......		Do.	
....	From rear and right.	......		30 yards beyond; 10 yards to right.	
....		......		In front and beyond. All about 10 yards right.	
....		......		20 yards beyond.	
....		......		5 or 6 feet to right.	
....		......		All around targets.	
....		......		Most of them beyond. One hit.	
....		......		In front and beyond.	
....		......		Beyond.	
....		......		Do.	
....	....	......		Fired over water.	
....	From front and left.	......	Fired at 2,400-yard target.	Not found.	Gun aimed 15 yards to left.
....		......			Gun aimed 30 yards to left.
....		......			Do.
....		......			Do.
....		......			Do.
....		......			Gun aimed 55 yards to left.
....		......			Do.
....		......			Gun aimed 30 yards to left.
....		......			Do.
....		......			Do.
....		......			Do.
....		......			Do.
....		......			Do.

Target record of firing with caliber 0″.45 Gatling gun, English No. 1,

	Number of fire.	Time.	Ammunition.	Elevation.	
		1882.		° ′	
Barometer, 30.314; thermometer, 75; relative humidity, 60; wind, 10 miles an hour.	10	Aug. 1	English solid-head cartridge; charge, 85 grains; bullet, 480 grains.	55 00	Target inclined slightly from beach.
	10	Aug. 1	......do	50 00	
	20	Aug. 1	......do	50 00	
	10	Aug. 1	......do	45 00	
	20	Aug. 1	......do	45 00	
	20	Aug. 1	......do	60 00	
	10	Aug. 1	......do	60 00	
	20	Aug. 1	......do	60 00	
	20	Aug. 1	......do	60 00	
	20	Aug. 1	......do	50 00	
	25	Aug. 1	......do	55 00	
	25	Aug. 1	......do	55 00	
	50	Aug. 1	......do	56 00	
Barometer, 30.283; thermometer, 76; relative humidity, 52; wind, 12 miles an hour.	5	Aug. 1	......do	70 00	
	5	Aug. 1	......do	70 00	
	10	Aug. 1	......do	65 00	
	10	Aug. 1	......do	60 00	
	10	Aug. 1	......do	58 00	
	20	Aug. 1	......do	60 00	
	60	Aug. 1	English solid-head cartridge; charge, 80 grains; bullet, 410 grains.	62 00	
	20	Aug. 1	......do	62 00	
	20	Aug. 1	......do	64 00	
	25	Aug. 1	......do	64 00	
Barometer, 30.014; thermometer, 78; relative humidity, 70; wind, 12 miles an hour.	20	Aug. 3	English solid-head cartridge; charge, 85 grains; bullet, 480 grains.	64 00	
	20	Aug. 3	......do	64 00	
	20	Aug. 3	......do	65 00	
	15	Aug. 3	......do	*65 00	
	20	Aug. 3	......do	65 00	
	20	Aug. 3	......do	65 00	
	20	Aug. 3	......do	65 00	
	20	Aug. 3	......do	65 00	
	20	Aug. 3	......do	67 00	
	17	Aug. 3	......do	*65 00	
	20	Aug. 3	......do	65 15	
	20	Aug. 3	......do	65 15	
	20	Aug. 3	......do	65 15	
	20	Aug. 3	......do	65 30	
	20	Aug. 3	......do	65 30	
	11	Aug. 3	......do	*65 45	
	18	Aug. 3	......do	*66 00	
	20	Aug. 3	......do	66 00	
	36	Aug. 3	......do	66 00	
	20	Aug. 3	......do	66 10	
	20	Aug. 3	......do	66 15	
	20	Aug. 3	......do	66 15	
	40	Aug. 3	......do	66 15	
	40	Aug. 3	......do	66 12	
	40	Aug. 3	......do	66 13	
	20	Aug. 3	......do	66 15	
	8	Aug. 3	......do	*66 18	
	20	Aug. 3	......do	66 18	
	20	Aug. 3	......do	66 20	
	20	Aug. 3	......do	66 30	
	40	Aug. 3	......do	66 30	
	50	Aug. 3	......do	66 30	
Barometer, 29.931; thermometer, 72; relative humidity, 97; wind, 6 miles an hour.	3	Aug. 5	......do	5 00	
	8	Aug. 5	......do	3 00	
	10	Aug. 5	......do	75 00	
	20	Aug. 5	......do	77 00	
	20	Aug. 5	......do	76 30	
	20	Aug. 5	......do	76 45	
	20	Aug. 5	......do	77 00	
	20	Aug. 5	......do	77 15	
	50	Aug. 5	......do	77 15	
	50	Aug. 5	......do	77 15	

* Gun jammed. Jamming caused by empty shells dropping

at Sandy Hook, N. J., &c. Short barrel with drum feed—Continued.

Instrumental velocity, taken at 50 feet from muzzle.	Direction of wind as regards line of fire.	Time of flight.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Feet.		*Secs.*		
	From front and left.		Fired at 2,400-yard target.	Not found. Gun aimed 30 yards to left.
				Do.
				Do.
				Do.
				Do.
				Do.
				Gun aimed 50 yards to left.
				Gun aimed 60 yards to left.
				Gun aimed 120 yards to left.
				150 yards beyond; 50 yards to right. Gun aimed 120 yards to left.
				20 feet beyond; line good. Gun aimed 130 yards to left.
				Most of them beyond. One hit. Gun aimed 130 yards to left.
				One hit—through 1-inch board and 5 inches in sand. Gun aimed 130 yards to left.
			Fired at 2,000-yard target.	75 yards beyond. Gun aimed 25 yards to left.
				150 yards short; 50 yards right. Gun aimed 25 yards to left.
				Not found. Gun aimed 60 yards to left.
				Not found. Gun aimed 40 yards to left.
				Do.
				Not found.
				100 yards to right.
				100 yards to right and 100 yards beyond. Gun aimed 120 yards to left.
				120 yards to right. Gun aimed 130 yards to left.
				Gun aimed 140 yards to left.
			Fired at 2,000-yard target. Target inclined slightly from beach.	Not found. Gun aimed 70 yards to left.
				Not found. Gun aimed 75 yards to left.
				To right. Gun aimed 70 yards to left.
				Beyond and right. Gun aimed 100 yards to left.
				Beyond and right. Gun aimed 150 yards to left.
				Not found. Gun aimed 200 yards to left.
				Heard near target. Gun aimed 250 yards to left.
				50 yards beyond. Gun aimed 250 yards to left.
				Not found. Gun aimed 250 yards to left.
				10 yards beyond. Gun aimed 250 yards to left.
				Beyond. Gun aimed 250 yards to left.
				10 feet beyond; 10 feet left. Gun aimed 245 yards to left.
				Do.
				20 yards beyond. Line left edge of targets. Gun aimed 240 yards to left.
				30 yards beyond; 10 yards left. Gun aimed 240 yards to left.
				40 yards beyond. Gun aimed 245 yards to left.
				10 yards left. Gun aimed 245 yards to left.
				All around target. Gun aimed 245 yards to left.
				10 to 20 yards beyond; 20 yards left. Gun aimed 245 yards to left.
				10 to 20 yards beyond; 20 yards left. Gun aimed 240 yards to left.
				Left of targets. Gun aimed 240 yards to left.
				2 hits. One bullet went through two 1-inch boards and 3 inches in sand. Gun aimed 235 yards to left.
				1 hit.
				1 hit.
				2 to 60 yards beyond target. Gun aimed 235 yards to left.
				50 yards beyond; 20 yards left. Gun aimed 235 yards to left.
				15 yards right. Gun aimed 235 yards to left.
				30 yards beyond; 10 yards right. Gun aimed 235 yards to left.
				10 to 50 yards beyond; 2 to 8 yards left. Gun aimed 235 yards to left.
				In front and beyond. Two hits. Gun aimed 235 yards to left.
				All around target. Gun aimed 235 yards to left.
				Do.
	From left to right.		Fired at 1,000-yard target. Target inclined slightly from beach.	Beyond target. Gun aimed 150 yards to left.
				10 to 100 yards short. Gun aimed 175 yards to left.
				150 yards beyond and right.
				75 yards left and 20 yards short.
				10 to 50 yards beyond.
				75 to 100 yards beyond.
				50 yards beyond.
				All around target. One hit. One bullet went through two 1-inch boards and 4 inches in sand.
				All around target. One hit.
				All around target.

in recess of lock cylinder ring so as to prevent extraction.

Target record of firing with caliber 0″.45 Gatling gun, English No. 1,

	Number of fire.	Time. 1882.	Ammunition.	Elevation. ° ′
Barometer, 29.683; thermometer, 82; relative humidity, 74; wind, 18 miles an hour.	20	Aug. 8	English solid-head cartridges; charge, 85 grains; bullet, 480 grains.	80 00
	20	Aug. 8	......do	82 00
Barometer, 29.748; thermometer, 80; relative humidity, 62; wind variable, from 7 to 16 miles an hour.	20	Aug. 9	......do	82 00
	20	Aug. 9	......do	80 00
	20	Aug. 9	......do	82 00
	20	Aug. 9	......do	85 00
	20	Aug. 9	......do	85 00
	20	Aug. 9	......do	85 00
	40	Aug. 9	......do	85 00
	20	Aug. 9	......do	*85 00
	20	Aug. 9	......do	85 00
	100	Aug. 9	English solid-head cartridges; charge, 80 grains; bullet, 410 grains.	85 00
	50	Aug. 9	English solid-head cartridges; charge, 85 grains; bullet, 480 grains.	85 00
	20	Aug. 9	......do	85 00
	40	Aug. 9	......do	85 00
	20	Aug. 9	......do	85 00
	40	Aug. 9	......do	85 00
	40	Aug. 9	......do	84 55
	40	Aug. 9	......do	84 55
	40	Aug. 9	......do	84 55
	40	Aug. 9	......do	84 55
	40	Aug. 9	......do	84 55
	40	Aug. 9	......do	84 55
	40	Aug. 9	......do	84 55
	40	Aug. 9	......do	84 55
Barometer, 30.092; thermometer, 74; relative humidity, 69; wind, 3 to 6 miles.	20	Sept. 7	......do	85 00
	20	Sept. 7	......do	85 00
	100	Sept. 7	......do	85 00
	1	Sept. 7	......do	85 00
	2	Sept. 7	......do	85 00
	20	Sept. 7	......do	85 00
	20	Sept. 7	......do	85 00
	2	Sept. 7	......do	85 00
	20	Sept. 7	......do	85 00
	20	Sept. 7	......do	85 00
	20	Sept. 7	......do	85 00
	100	Sept. 7	......do	85 00
	100	Sept. 7	......do	85 00
Barometer, 30.005; thermometer, 76; relative humidity, 64; wind, 14 miles.	20	Sept. 7	......do	86 00
	20	Sept. 7	......do	87 00
	1	Sept. 7	......do	....
	1	Sept. 7	......do	....
	1	Sept. 7	......do	....
	3	Sept. 7	......do	....
	3	Sept. 7	......do	....
	100	Sept. 7	......do	....
	103	Sept. 7	......do	....
	207	Sept. 7	......do	....
	312	Sept. 7	......do	....
	104	Sept. 7	......do	....
	104	Sept. 7	......do	....
	104	Sept. 7	......do	....

* One miss fire.

at Sandy Hook, N. J., &c. Short barrel with drum feed—Continued.

Instrumental velocity, taken at 50 feet from muzzle.	Direction of wind as regards line of fire.	Time of flight.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
Feet.		*Secs.*		
....	From front and right.	......	Fired at 500-yard targets. Targets inclined slightly from beach.	Left and beyond. Gun aimed 30 yards to right.
....		......		Left. Gun aimed 40 yards to right.
....		......	Fired at 500-yard targets. Targets inclined slightly from beach.	Not found. Gun aimed 40 yards to right.
....		......		Not found. Gun aimed 50 yards to right.
....		......		Beyond. Gun aimed 50 yards to right.
....		......		Not found. Gun aimed 50 yards to right.
....		......		Not found. Gun aimed 60 yards to right.
....		......		Left. Gun aimed 30 yards to right.
....		......		Do.
....		......		Left, and 30 yards beyond. Gun aimed 40 yards to right.
....		......		Left. Gun aimed 50 yards to right.
....		......		125 yards left. Gun aimed 40 yards to right.
....		......		75 yards left and 40 yards beyond. Gun aimed 60 yards to right.
....		......		20 yards short; 20 yards left. Gun aimed 80 yards to right.
....		......		20 yards beyond; 45 yards left. Gun aimed 80 yards to right.
....		......		50 feet right. Gun aimed 85 yards to right.
....		......		5 yards short; 35 yards left. Gun aimed 95 yards to right.
....		......		5 yards short; 35 yards left.
....		......		Not found.
....		......		Do.
....		......		75 yards left; 20 yards short.
....		......		125 yards left; 20 yards short.
....		......		70 yards left; 20 yards short.
....		......		50 yards left; 45 yards short.
....		......		25 yards left; 10 yards short.
....		......	Fired at 500-yard targets. Horizontal targets.	25 yards to right. Gun aimed 25 yards to right of targets.
....		......		All around targets. Several hits. Gun aimed at targets.
....	From front and left.	......		10 yards to right. Gun aimed at targets.
....		......		Lost. Gun aimed at targets.
....		......		Do.
....		56		Left. Gun aimed at targets.
....		56¼		Do.
....		......		Lost. Gun aimed at targets.
....		58		125 yards to left of targets. Gun aimed at targets.
....		......		Left edge of targets. Gun aimed 20 yards to right of targets.
....		57		In front and beyond. One hit. Gun aimed 25 yards to right of targets.
....		57		All around targets. Several hits. Gun aimed 25 yards to right of targets.
....		56		Do.
....		......	Fired at 200-yard targets. Horizontal targets.	Not found. Gun aimed 5 feet to left of target.
....		......		50 yards beyond and 75 yards left. Gun aimed 5 feet to left of target.
....		......	Fired over water.	
....		......		
....		......		
....		......		
....		......		
....		......		
....		......	Fired over water by Mr. Accles (expert). Time of firing, 8¼ seconds.	
....		......	Fired over water for rapidity, by Mr. Accles (expert), he taking out empty feed-case and putting in full one, handing the empty one to another man. Time of firing 10¼ seconds.	
....		......	Fired over water. Number 312 and the three following, each 104 of September 7, were fired as rapidly as possible with sudden stoppings and startings made after three turns of the crank (crank in rear). The 312 by Mr. Accles (expert), and the remainder, of 104 each, by Lieutenant-Commander Folger, U. S. N.	
....		......		
....		......		
....		......		

Target record of firing with caliber 0''.45 Gatling gun, English No. 1

	Number of fire.	Time.	Ammunition.	Elevation.
		1882.		° '
Barometer, 29.973; thermometer, 74; relative humidity, 76; wind, 12 to 18 miles.	20	Sept. 8	English solid-head cartridges; charge, 85 grains; bullet, 480 grains.	87 [illegible]
	20	Sept. 8	......do	87 [illegible]
	20	Sept. 8	......do	88
	20	Sept. 8	......do	88 [illegible]
	40	Sept. 8	......do	88 [illegible]
	40	Sept. 8	......do	88 [illegible]
	100	Sept. 8	......do	88 [illegible]
	100	Sept. 8	......do	88 [illegible]
	100	Sept. 8	......do	88 [illegible]
Total	5,436			

Time of filling feedcase:

	'	''
First trial	2	14
Second trial	2	24
Third trial..............	2	53
Average	2	30⅓

at Sandy Hook, N. J., &c. Short barrel with drum feed—Continued.

Instrumental velocity, taken at 50 feet from muzzle.	Direction of wind as regards line of fire.	Time of flight.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Feet.		*Secs.*		
....	From right and rear.	......	Fired at 200-yard targets. Horizontal targets.	225 yards to left of target. Gun aimed 30 yards to right of targets.
....		......		100 yards beyond and trifle left. Gun aimed 60 yards to right of targets.
....		......		50 yards beyond and 50 yards to right. Gun aimed 60 yards to right of targets.
....		......		50 yards beyond. Line good. Gun aimed 30 yards to right of targets.
....		......		20 feet to right of target. Gun aimed 30 yards to right of targets.
....		......		2 hits on target. Rest to right. Gun aimed 20 yards to right of targets.
....		......		All around target. Several hits. Gun aimed 20 yards to right of targets.
....		......		Elevation good. Twenty-five feet to right. Gun aimed 20 yards to right of targets.
....		......		Elevation good. Twenty-five feet to right. Gun aimed 15 yards to right of targets.

NOTE.—All projectiles recovered from the 500 and 200 yard targets (vertical firing of September 7 and 8) were found to have struck butt first or sideways. The penetration varying from ¼-inch to ¾-inch, majority of them being of the lighter penetration.

The targets arranged in the following order were used for all vertical firing, being ten in number.

The targets in the first and second rows, 1-inch thick; in the third and fourth rows, 2 inches thick.

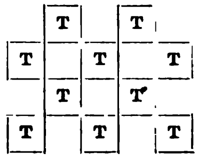


PLATE I.

Fig. 1.

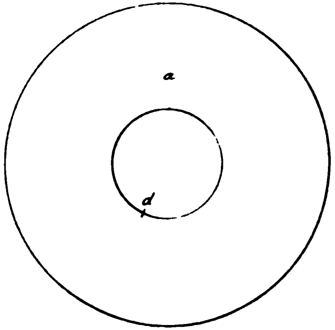


Fig. 2.

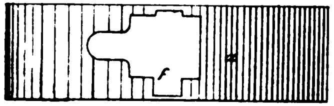


Fig 3.

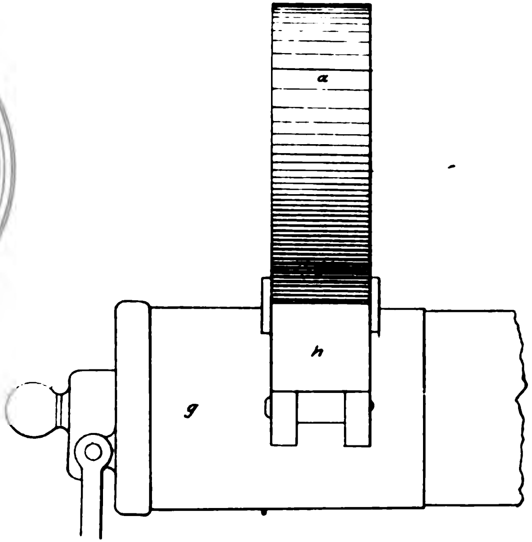
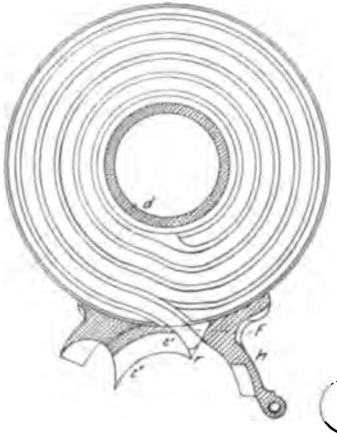


Fig. 4.



SCALE OF 12 6 3 0 1 2 3 4 5 6 7 8 9 10 INCHES

U. S. Ordnance Board
Governor's Island Oct. 11th 1882

Appendix 26—1883.

PLATE II.

Fig. 5.

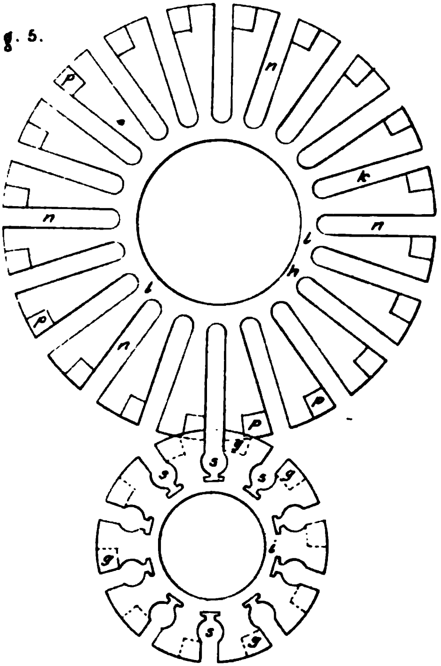
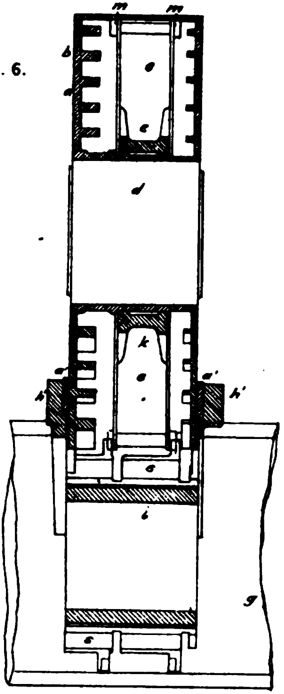


Fig. 6.



SCALE OF 1 0 9 ... 1 2 3 4 5 6 7 8 INCHES.

U. S Ordnance Board
Governor's Island Oct. 11th 1882.

PLATE III.

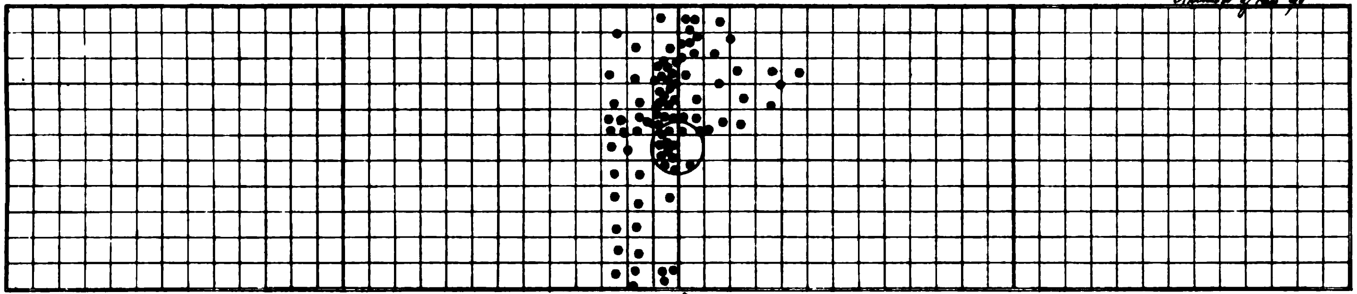
TARGET RECORD OF Calibr .45" English Gatling Gun No 1 (short Barrel)

June 24/82 AT SANDY HOOK, N. J.

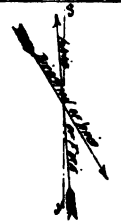
Target 500 yards from Gun.

Number of shots fired: 100

Number of hits 91



Target 11' × 58'. Made of 1" spruce boards.



Wind 17 miles per hour.

PLATE IV.

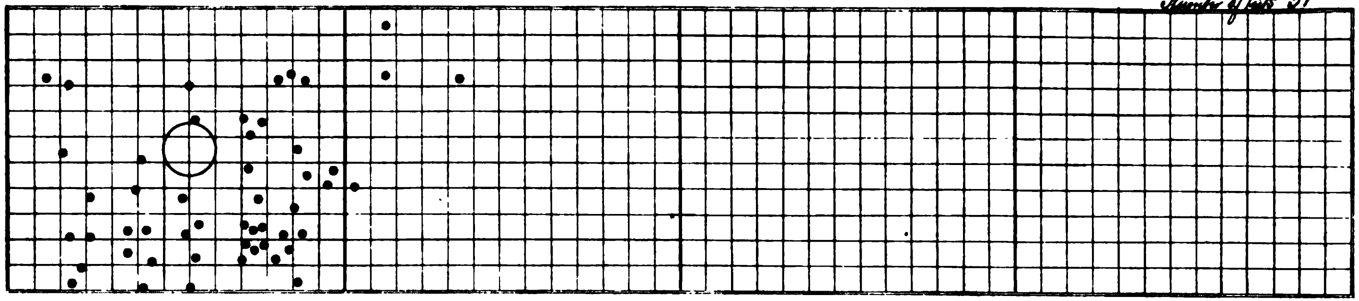
TARGET RECORD OF Calibre .45" Gatling Gun. American No 719 (Short barrel)

July 27/82 AT SANDY HOOK, N. J.

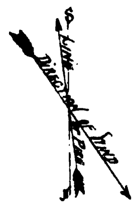
Target 500 yards from Gun.

Number of shots fired: 100

Number of hits 51



Target 11' × 58'. Made of 1" fence boards



Wind 17 miles per hour.

APPENDIX 27.

TRIAL OF A HOTCHKISS FLANK-DEFENSE REVOLVING CANNON, CALIBER 1.5748 *INCHES* (40 *MILLIMETERS*).

(11 plates.)

In accordance with the ninth indorsement on Ordnance Office file No. 3,269 of 1882, the Hotchkiss flank-defense revolving cannon was tried at Sandy Hook during the months of August and October, 1882.

THE GUN AND CARRIAGE.

The piece was constructed in the same way as the one described in Appendix "I⁷" of the Report of the Chief of Ordnance for 1879, page 173, except that the twists of the grooves varied in each barrel. The carriage was the one referred to in the same report, and shown on Plate I of Appendix "I⁶."

THE AMMUNITION.

The projectile used was a canister of tinned iron containing 24 lead bullets forced into the anterior extremity of a spirally-rolled tube of sheet brass which contained the powder charge of 3 ounces. A drawing hereto appended, and marked "Plate XI," shows the details of this ammunition, which weighed when assembled for use 2 pounds 5 ounces.

OBJECT OF THE GUN.

The gun is designed for the flank defense of works in which the exterior slope is carried to the bottom of the ditch. The ditches of such works are narrow and their ramparts are acccessible throughout their whole length except in the vicinity of the caponieres where the escarp galleries debouch.

The piece should fulfill the following conditions:

1st. It must be placed from 9 to 10 feet above the level of the bottom of the ditch to prevent its fire being masked by hastily constructed traverses. With a piece so situated a dead space would exist for a distance of from 13 to 15 yards from the muzzle. This is covered by fire from places in the head of the caponiere and the escarp galleries and by grenades.

2d. The piece should sweep the whole width of the ditch, as an enemy might be tempted to assail the whole front at once.

3d. In order to protect the work against surprise the mechanical arrangements should be such as to require a small number of men to operate the piece.

Neither a gun nor a howitzer would fulfill the above conditions, and heretofore, when mitrailleuses have been used, a vibratory action of the barrels was necessary in order to cover the horizontal space to be protected, and a change of elevation would be required to cover the shortest and longest ranges, were the piece mounted at the required height. By varying the twist of the grooves the spread of the bullets from the gun now under consideration is such as would take place from a smoothbore enhanced by the rotary motion due to rifling. The grooves in the first barrel have one turn in 39.4 inches; those in the fifth barrel are almost rectilinear. By varying the twist the area of the cone of dispersion may be correspondingly varied.

When the grooves are so constructed as to fulfill the conditions for any particular work no change has to be made in either the direction or elevation of the piece. An inclined table supplied with cartridges is provided, and the mechanical arrangements are such that one man can produce an effective fire immediately, and thus the third condition is fulfilled.

Ordnance Notes No. 178 explain the theory by which, from the required dispersion, the twist of the different barrels is determined.

TRIAL OF THE GUN.

The object of the trial was to ascertain if the gun fulfilled the conditions for which it was constructed, and a programme previously submitted to the Chief of Ordnance was by his direction carried out. The principal points were as follows:

That the gun be placed about ten feet above the level of the ground.

That targets 50 feet long, 5 feet 9 inches high, be placed at intervals of 50 yards (beginning at a point 15 yards in front of the gun) up to a distance of 328 yards.

"That firing for accuracy and dispersion be carried on, and the vertical and horizontal targets be plotted in order to ascertain the effectiveness of the gun."

Before carrying out this programme the gun was mounted on its carriage (the latter resting on the ground) and a shot was fired from each barrel. The targets numbered consecutively from 1 to 5 show the dispersion for each barrel for 15 yards. Five shots were then fired in succession at a similar target and are plotted on the accompanying plate, numbered 6.

The gun was then mounted on a stout scaffolding; one target was placed at a distance of 15 yards in front of the piece and six others were arranged at intervals of 50 yards, making the distance from the last target to the muzzle of the gun 315 yards.

A few preliminary rounds were fired to fix the most suitable height for the gun, and finally an elevation of 10′ for the lowest barrel was adopted as the proper height.

Three series of 60 rounds each were then fired, and the results were plotted on the accompanying plates, numbered VII, VIII, and IX. It is to be observed that these targets were placed upon the sand, and projectiles which passed to one side were free to continue in their divergent paths, while in a ditch they would have been deflected toward the target by the slope or the counterscarp wall. The number of hits would thus have been greatly increased.

SUMMARY.

The plotted targets (plates VII, VIII, and IX) and the target records inclosed show the effect of the fire with all details, but tables are given for comparison. The horizontal dangerous spaces are plotted on Plate X. The term "effective hits" has been applied in the following tables only to such shots as completely penetrated the 1-inch spruce boards of which the targets were made.

Each target has been divided into spaces of 24 inches, and such spaces are supposed to represent a file. From the number of spaces struck an estimate of the number of files hit has been made and is given in the tables.

Table I, deduced from plate VII.

Number of rounds fired	60	Number of effective hits	1,414
Number of files on each target	26	Total number of hits	1,695
Number of files on plate	182		

Number of target.	Distance from gun.	Effective hits.		Files hit.	
		Number.	Per cent.	Number.	Per cent.
	Yards.				
1	15	2	0.1	1	3.[illegible]
2	65	424	30.0	16	61.5
3	115	411	29.1	26	100.
4	165	265	18.7	26	100.
5	215	196	13.7	26	100.
6	265	78	5.5	24	92.3
7	315	38	2.7	18	69.2
Total..	....	1,414	....	137	75.2

Table II, deduced from plate VIII.

Number of rounds fired............	60	Number of effective hits	1,409
Number of files on each target.....	26	Total number of hits..............	1,752
Number of files on plate	182		

Number of target.	Distance from gun.	Effective hits.		Files hit.	
		Number.	Per cent.	Number.	Per cent.
	Yards.				
1	15	3	.2	2	8.0
2	65	459	32.6	16	61.5
3	115	444	31.5	26	100.
4	165	259	18.4	25	96.1
5	215	156	11.1	25	96.1
6	265	61	4.3	24	92.3
7	315	27	1.8	16	61.5
Total..	....	1,409	....	134	73.6

Table III, deduced from plate IX.

Number of rounds fired............	60	Number of effective hits	1,589
Number of files on each target	26	Total number of hits..............	1,874
Number of files on plate...........	182		

Number of target.	Distance from gun.	Effective hits.		Files hit.	
		Number.	Per cent.	Number.	Per cent.
	Yards.				
1	15	3	.2	1	.4
2	65	554	34.7	17	65.3
3	115	485	30.	25	96.1
4	165	315	19.8	26	100.
5	215	151	9.	23	88.4
6	265	60	4.0	22	84.6
7	315	21	1.3	13	50.
Total..	....	1,589	....	127	69.8

Attention is again invited to the fact that in a ditch the number of hits would have been greater than the accompanying plates and tables indicate.

CONCLUSION.

The Hotchkiss revolving cannon is well known now in nearly every service, and its great value as a military weapon admitted. The gun under consideration differs only from the former in the introduction of a new and special rifling for each barrel in order to give a varying dispersion to canister shot sufficient to cover the length and breadth of the ditch of a work.

The results of the firing with this special gun clearly proves that guns constructed on this principle would be a most valuable adjunct to the armament for the flank defense of works of the same character as that for which the gun was designed. The short ranges incident to this special service and the very small space left uncovered by this gun would render its fire very destructive to the *personnel* of an enemy.

Record of firing with Hotchkiss revolving cannon, No. 797, caliber

[French model

		No. of rounds.	Time.	Powder.		Projectile.		
				Kind.	Weight	Kind.	Weight.	
			1882.		*Ozs.*		*Lbs.*	*Ozs.*
Barometer, 30.094; thermometer, 77; relative humidity, 69; wind, 17 miles an hour.	Barrel No. 5	1	Aug. 26	Mortar.	3	Hotchkiss canister, containing 24 lead balls 0''.7 diameter; tin case and lead base.	2	5
	......do	1	Aug. 26		3		2	5
	Barrel No. 4	1	Aug. 26		3		2	5
	Barrel No. 3	1	Aug. 26		3		2	5
	Barrel No. 2	1	Aug. 26		3		2	5
	Barrel No. 1	1	Aug. 26		3		2	5
	......do	1	Aug. 26		3		2	5
	Barrel No. 2	1	Aug. 26		3		2	5
	Barrel No. 3	1	Aug. 26		3		2	5
	Barrel No. 4	1	Aug. 26		3		2	5
	Barrel No. 5	1	Aug. 26		3		2	5
Barometer, 29.942; thermometer, 59; relative humidity, 57; wind, 17 miles an hour.	Barrel No. 1	1	Oct. 25		3		2	5
	......do	1	Oct. 25		3		2	5
	......do	1	Oct. 25		3		2	5
Barometer, 29.913; thermometer, 61; relative humidity, 60; wind, 12 miles an hour.	......do	1	Oct. 26		3		2	5
	......do	1	Oct. 26		3		2	5
Barometer, 29.917; thermometer, 65; relative humidity, 68; wind, 13 miles an hour.		60	Oct. 26		3		2	5
Barometer, 30.174; thermometer, 46; relative humidity, 44; wind 6 miles an hour.		60	Oct. 27		3		2	5
		60	Oct. 27		3		2	5

40 mm., at Sandy Hook, N. J., from August 26 to October 27, 1882.

for flank defense.]

Elevation.	Direction of wind as regards line of fire.	Time of firing.	Gun mounted on flank-defense carriage.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
° ′		*Secs.*		
1	From left to right.	......	Fired at 200-yard target........................	Number of direct and ricochet hits on target, 12.
0		......	Fired at target 45 feet from muzzle of gun..	Number of direct hits on target, 24. Target No. 1.
0		......	......do	Number of direct hits on target, 24. Target No. 2.
0		......	......do	Number of direct hits on target, 24. Target No. 3.
0		......	......do	Number of direct hits on target, 24. Target No. 4.
0		......	......do .... (Target made by each barrel in the above firing plotted separately.)	Number of direct hits on target, 24. Target No. 5.
0		......	Fired at a target 45 feet from muzzle of gun. Number of direct hits on target, 120. One target plotted of hits made by all five barrels.	Target No. 6.
0		......		
0		......		
0		......		
0		......		
			Gun mounted on flank-defense carriage on elevated platform.	
0	From rear and right.	......	Fired at target 45 feet from gun. Target 6′×26′; top of target 4 feet below axis of barrel fired. No hits except butt, making slight indentation.	
— 5		......	Fired at target 45 feet from gun. Target 6′×26′; top of target 4 feet below axis of barrel fired. No hits except butt and case, making slight indentation.	
0		......	Fired at target 45 feet from gun. Target 6′×26′; top of target 2 feet 6 inches below axis of barrel fired. Five hits in target. (Top division.)	
—1 5		......	Fired at targets. Six targets in column. First target 45 feet from gun; other targets 50 yards apart. 1st and 2d targets 6′×26′, 3d, 6′×39′, 4th, 5th, and 6th 6′×52′. Top of target 4 feet below axis of barrel fired. Number of hits on target 18 (1st target 2, 2d target 8, 3d target 4, 4th target 2, 5th target 0, 6th target 2).	
—1 5		......	Fired at targets. Six targets in column. First target 45 feet from gun; other targets 50 yards apart. 1st target 6′×26′, 2d target 6′×39′, 3d, 4th, 5th, and 6th targets 6′×52′. Top of target 4 feet below axis of barrel fired. Number of hits on target 28 (1st target 0, 2d target 15, 3d target 7, 4th target 8, 5th target 1, 6th target 2).	
0	From right and rear.	......	Fired at targets. Seven targets in column. First target 45 feet from gun; other targets 50 yards apart. 1st target 6′×26′, 2d target 6′×39′, 3d, 4th, 5th, 6th, and 7th, 6′×52′. Top of target 4 feet below axis of barrel fired.	Total number of hits in seven targets, 1,695. Target No. 7.
[illegible]		51¼		Total number of hits in seven targets, 1,752. Target No. 8.
[illegible]		47¾		Total number of hits in seven targets, 1,874. Target No. 9.

NOTE.—The barrels of this gun are rifled with different twists—barrel No. 5 having the least; the twist being more rapid in each barrel from 5 to 1.

Barrel No 5 TARGET RECORD OF Hotchkiss Revolving Cannon # 797 Cal 40 m/m (French model for flank defence) Target No. 1.

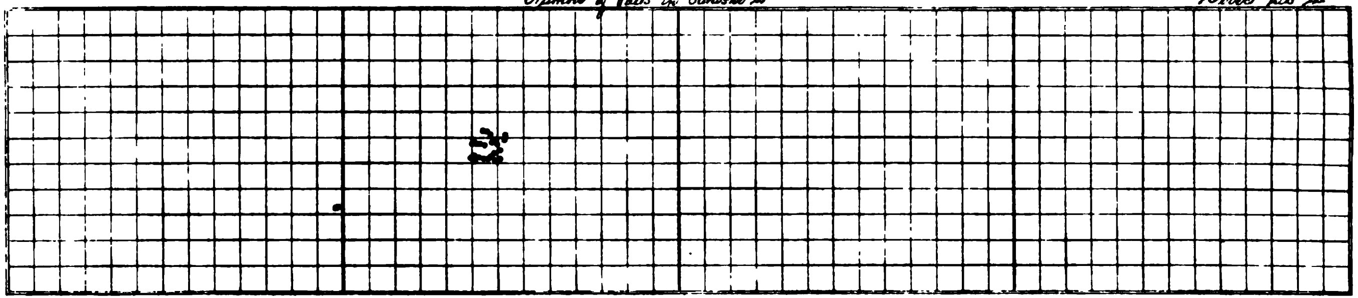
August 26/82 AT SANDY HOOK, N. J.

Target 145 feet from Gun.

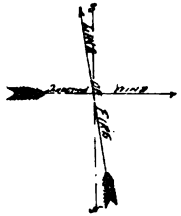
Number of shots fired: 1

Number of balls in canister 24

Direct hits 20



Target 11' × 58'.



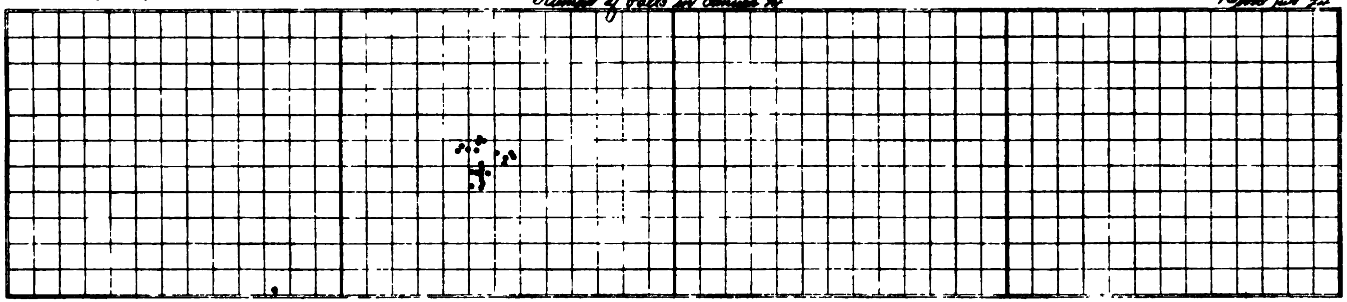
Wind 12 miles per hour

Round from — TARGET RECORD OF Hotchkiss Revolving Cannon # 797 Cal 40 m/m (French Model for Flank Defense) — Target No. 2

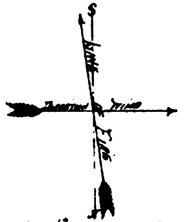
August 16/82 AT SANDY HOOK, N. J.

Target 40 feet from Gun.

Number of shots fired: 1 — Number of Balls in Canister 24 — Direct Hits 24



Target 11' × 58'.



Wind 12 miles per hour.

Barrel No 3 TARGET RECORD OF Hotchkiss Revolving Cannon #197 Cal. 40 mm (French Model for Flank Defense) Target No 3.

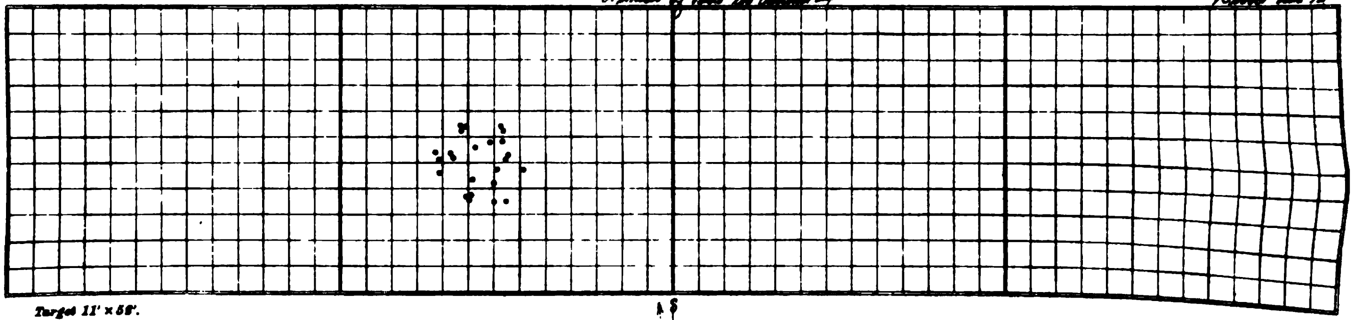
August 26/87 AT SANDY HOOK, N. J.

Target 145 feet from Gun.

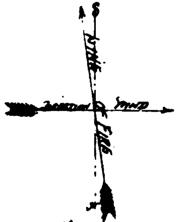
Number of shots fired: 1

Number of balls in canister 24

Direct hits 24



Target 11' × 58'.



Wind 13 miles per hour.

Barrel no 2 TARGET RECORD OF Hotchkiss Revolving Cannon No 797 Cal 40 m/m (French model for flank defense) Target No 4

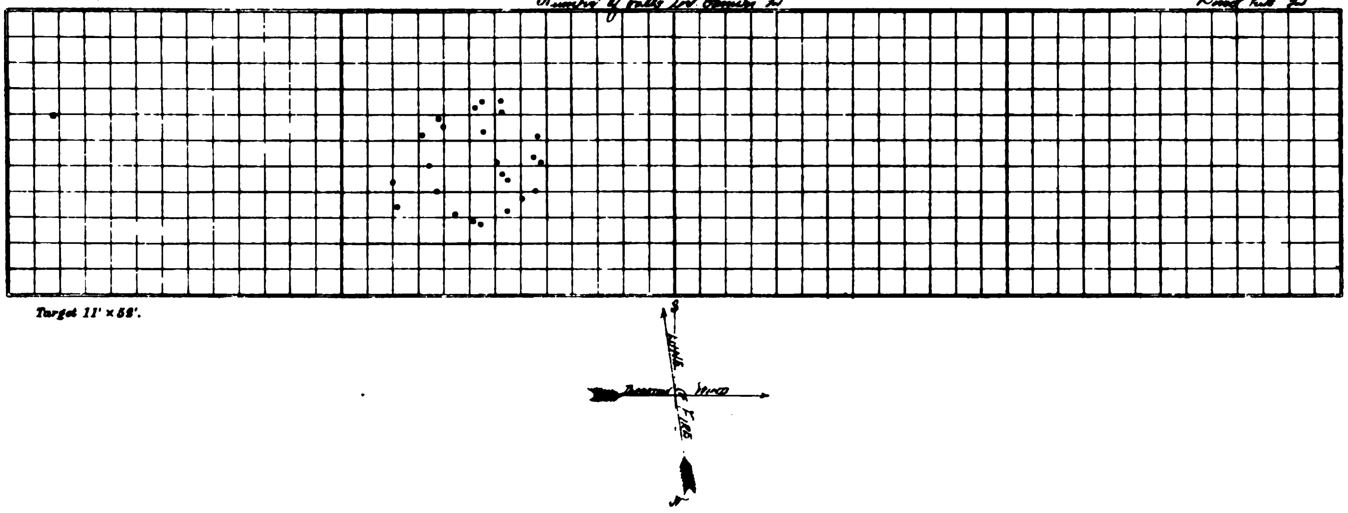
August 24/82 AT SANDY HOOK, N. J.

Target 45 feet from Gun.

Number of shots fired: ...

Number of balls in Canister 24

Direct hits 24



Target 11' × 58'.

Wind 12 miles per hour.

Barrel no 1 **TARGET RECORD OF** Hotchkiss Revolving Cannon No 797 Cal 37 mm (French Model for Flank Defense) . Target No 5

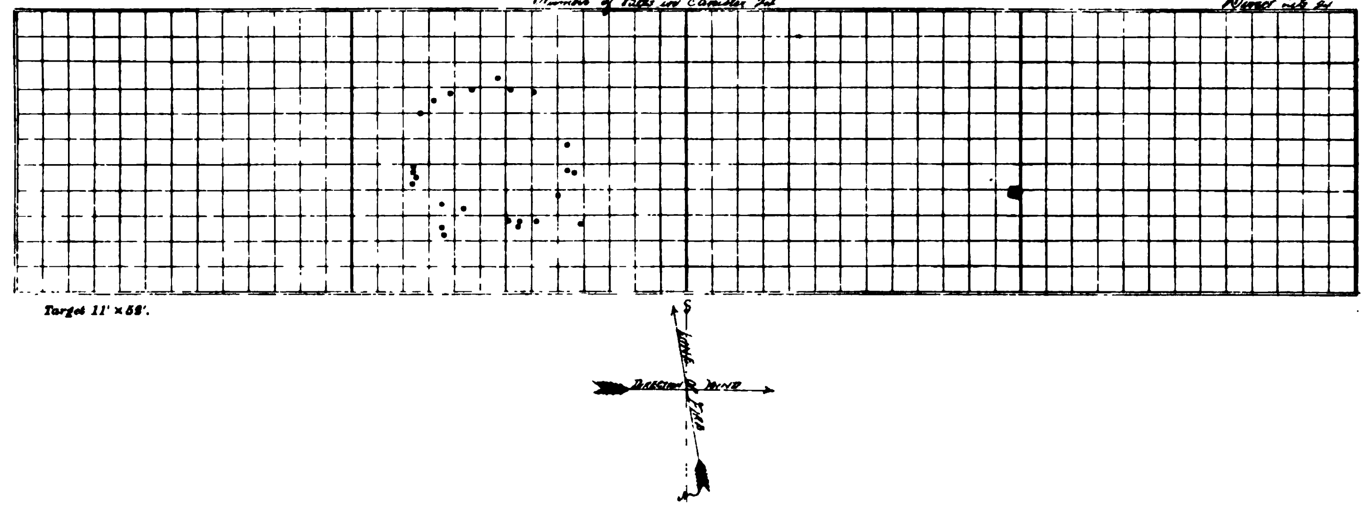
August 24/82 **AT SANDY HOOK, N. J.**

Target 45 feet *from Gun.*

Number of shots fired: 1

Number of balls in canister 24

Went into 24



Target 11' × 58'.

Wind 12 *miles per hour.*

Rounds nos 1 2 3 4 5 TARGET RECORD OF Hotchkiss Revolving Cannon 1.47 Cal. 40 m/m (Mounted for Flank Defence)

Target No 6

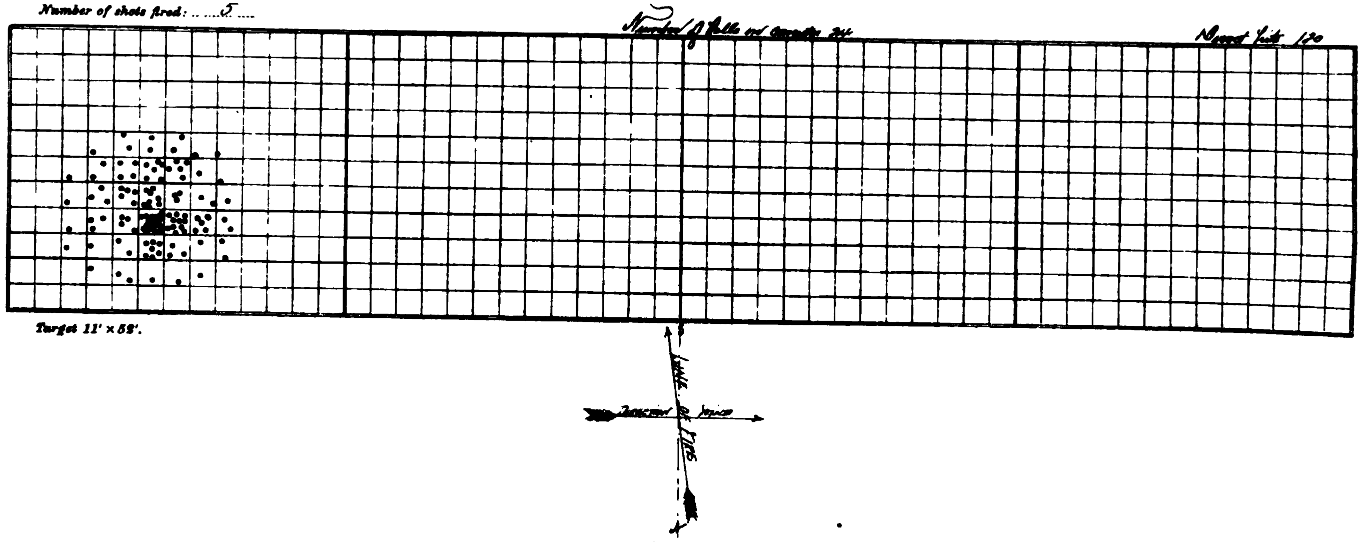
August 26/82. AT SANDY HOOK, N. J.

Target 45 feet from Gun.

Number of shots fired: 5

Number of Balls in Canister 24

Number hit 120



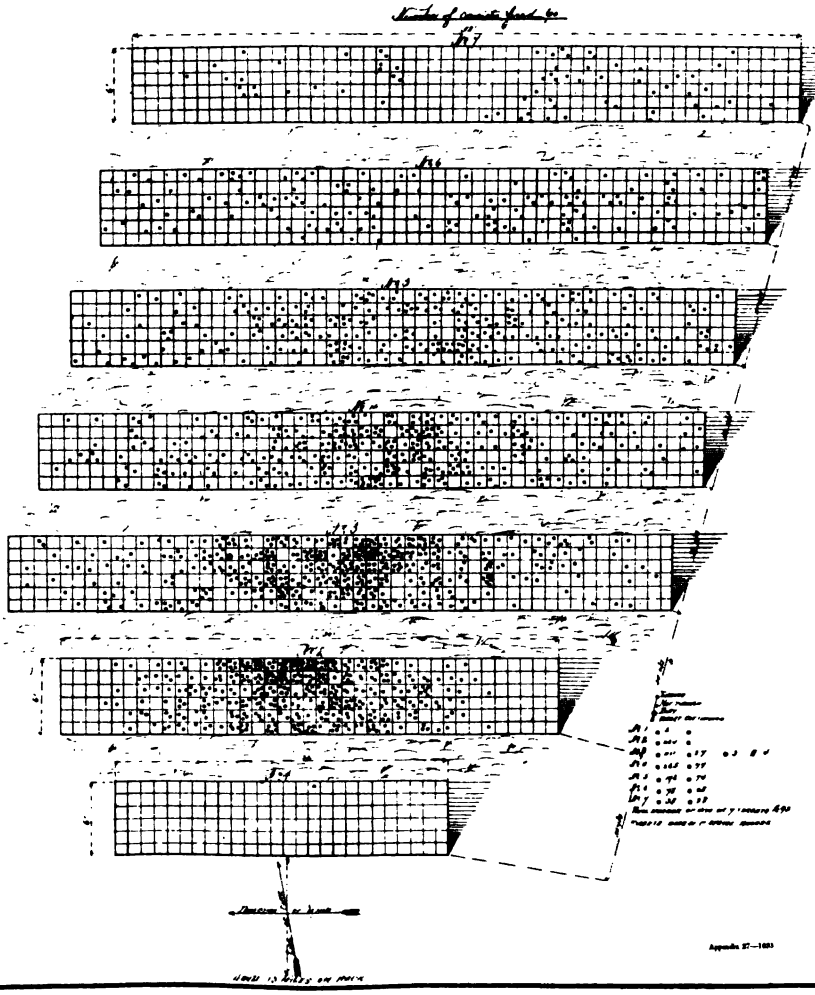
Target 11' × 52'.

Wind 12 miles per hour.

PLATE VII.

Target Record of Hotchkiss Revolving Cannon No 797 ([illegible] made for flank defense) Cal [illegible]

At Sandy Hook N. J. October 26 1882



Appendix 27—1883

PLATE VIII.

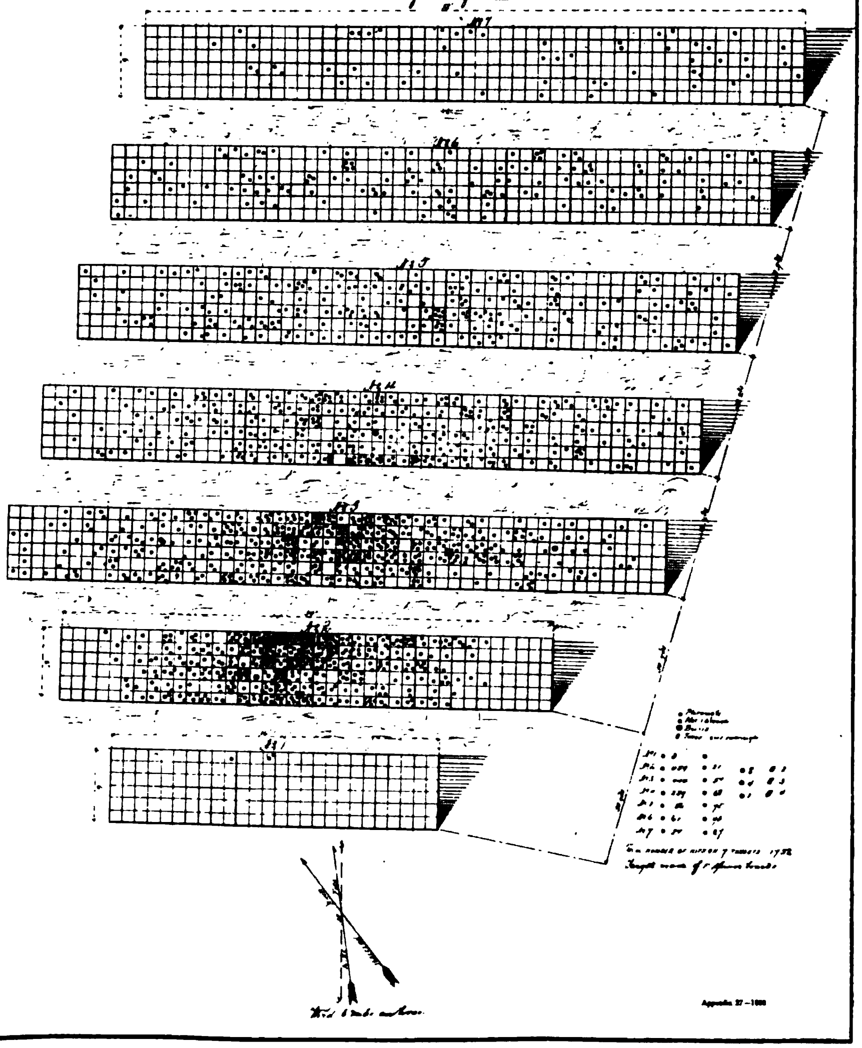
Target No 8 a)

Target Record of Hotchkiss Revolving Cannon No 797 ([illegible]) [illegible]

At Sandy Hook N. J. October 27th 1887

Guns 25 feet from the Target

Number of rounds fired 60



Appendix 27—1888

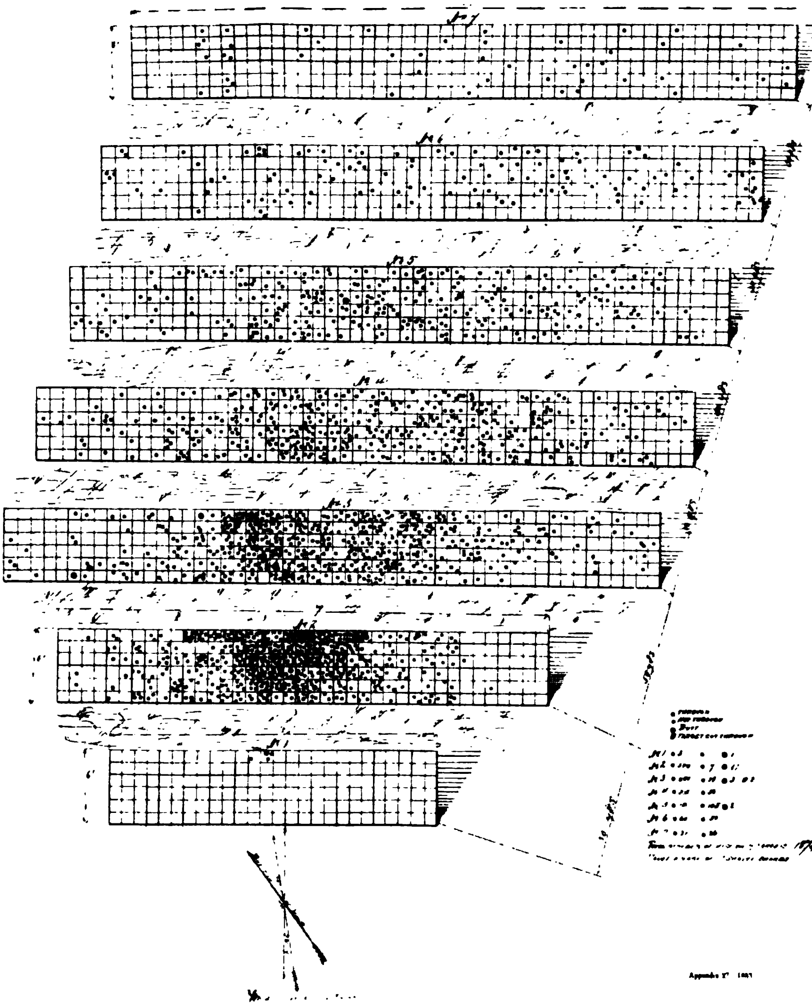
PLATE IX

Target No 9 (?)

Target Record of Hotchkiss Revolving Cannon No 797 (French model for flank defence) Cal. [illegible]

At Sandy Hook N.J. October 27th 1882

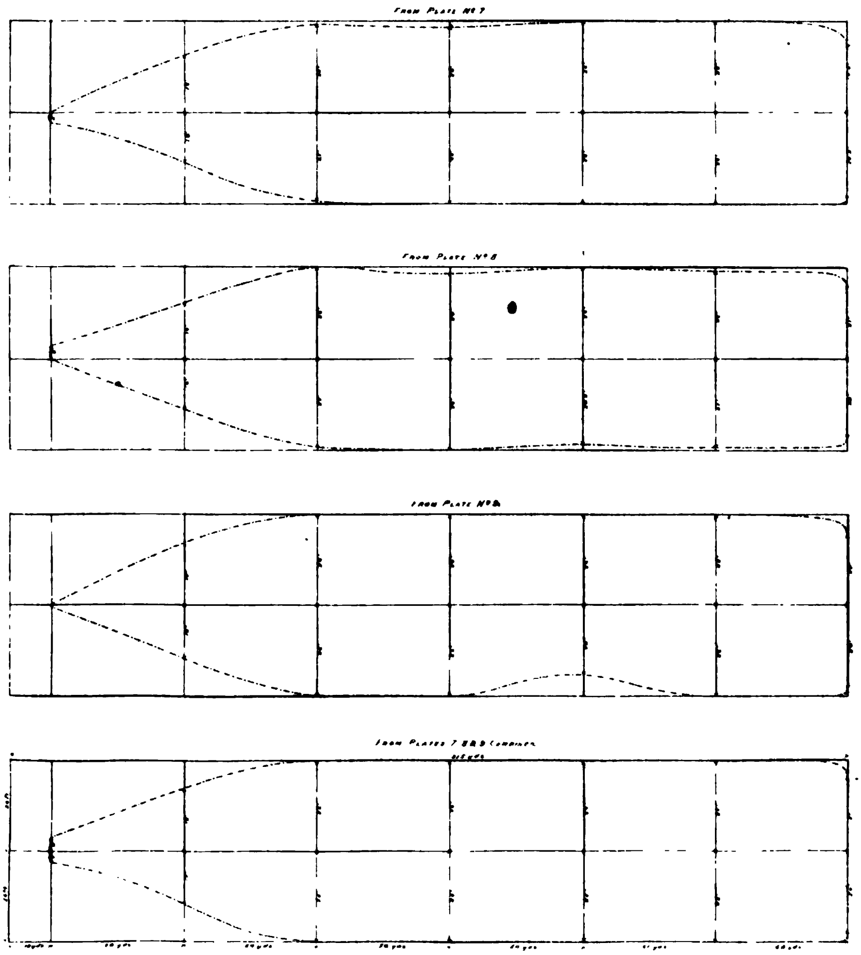
Number of rounds fired [illegible]



Appendix Y² 1883

HORIZONTAL DANGEROUS SPACES DEDUCED FROM VERTICAL TARGETS.

SHOWN IN PLATES No 7, 8 & 9 SEPARATELY AND COMBINED.

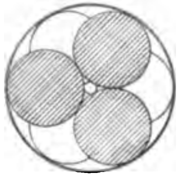


Note— Dotted lines enclose dangerous spaces

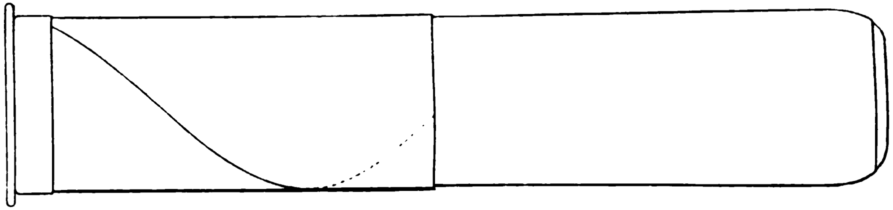
Appendix [illegible] 1883

PLATE XI.

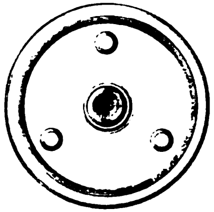
AMMUNITION FOR 1·574 INCH HOTCHKISS FLANK DEFENCE REVOLVING CANNON.



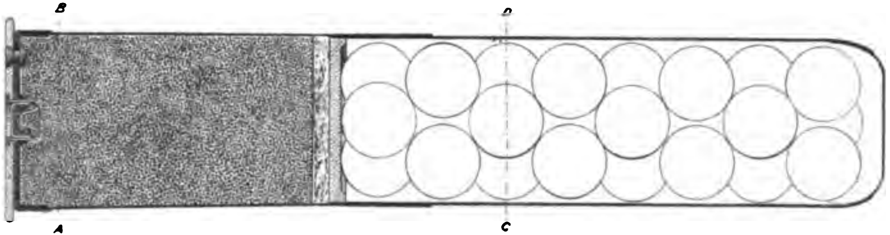
Section on C.D.



Exterior View.



Section on A.B.



Longitudinal Section.

Scale

APPENDIX 28.

TRIAL OF GATLING GUN, CALIBER .45 INCH, WITH NEW FEED MAGAZINE, MODIFIED.

(3 plates.)

This trial was carried on in accordance with directions given by the Chief of Ordnance November 22, 1882, in the first indorsement, on Ordnance Office file No. 5288.

THE GUN AND CARRIAGE.

The gun is similar in general to the one described in the last report of the Ordnance Board on the subject, but certain modifications have been introduced to overcome defects which appeared when high-angle firing was carried on. Only points of difference will be noted.

The *extractor* is so formed that its point remains always in front of the cartridge head, and is rendered stronger by making it double its former width circumferentially. It has no spring, and does not lift the lock by springing over the cartridge head; the cartridge is therefore always struck centrally instead of at one side.

The *lock* is called a rebounding one, the intention being that the firing-pin shall not project in front of the face of the lock until, when released from the cocking-ring, it flies forward and discharges the cartridge. A defect developed in firing, and referred to later, has caused the inventor to think it better to substitute a cam, so as to make the action of the pin positive.

In firing at high elevations with the first gun the cartridge was liable to slide back in the carrier-block, enter the orifice in the front lock-flange, and pass into the mechanism. To obviate this the openings have been reduced, and the anterior part of the lock has been flanged off correspondingly. The gun can, therefore, be fired even in a vertical position without difficulty, so far as such a movement of the cartridge is concerned. The rear portion of the lock is supported by a T-way at its center, instead of at the bottom, in order to prevent the possibility of jamming. There are minor details to permit the ready escape of dirt. A device allows the cocking-ring to be thrown out of action at will, and prevent the cocking of the hammers. This is of advantage during drill, and allows firing motion to take place without snapping, and thereby injuring the hammers.

The *feed magazine* is, to facilitate its adjustment and removal, attached to the piece by two undercut slots, instead of by hasps. By making the slots of unequal size it is impossible to reverse the position of the magazine and introduce the cases butt forward. The rear face is colored to distinguish it. It is adapted to the reception of either long cartridges carrying a 500-grain bullet or to short ones containing the 405-grain bullet.

The *carriage* has a circular elevating arc connected at both extremities with the gun and actuated by a gearing so arranged that elevation and depression is indicated in degrees and minutes. A horizontal limb for direction is graduated in the same way. The trail terminates in two sharp beaks, which will engage in a wooden platform and prevent recoil, while the rear transom plate effects the same purpose in earth or sand.

EXPERIMENTS.

As two different cartridges were to be tried, it was proposed to fire 50 of each at the 500-yard and the 1,000-yard targets, and plot the results. Owing to the unfavorable atmospheric conditions it was found impracticable to fire at 1,000 yards.

ACCURACY AT 500-YARD RANGE.

With the ordinary Frankford cartridge, containing 70 grains powder and a bullet of 405 grains, six sighting shots showed that 1° 15′ was a suitable elevation for 500 yards. Fifty shots were then fired in 2½ seconds, the result being shown on the left-hand side of the accompanying target. The same elevation was used with the Frankford solid-head cartridge, containing 70 grains powder and a bullet weighing 500 grains. Fifty rounds were fired in 1¾ seconds, the result being exhibited on the right-hand side of the target inclosed.

RAPIDITY OF FIRE.

In firing for rapidity, the feed magazines, filled with cartridges, were placed in a box just to the left of the piece. An assistant handed the magazine to the expert, who adjusted it in position and fired the gun. When a magazine was exhausted an assistant at the right removed it. For the ammunition carrying the 405-grain bullet nine magazines were provided, eight of them capable of containing the 500-grain bullet cartridge also. Each magazine held 104 cartridges, but they were not always entirely filled.

The rapidity of firing was as follows:

Date.	Kind of cartridge.	No. of rounds.	Time.
1883.			
January 4	500-grain bullet	926	1 minute 5 seconds.
January 4	405-grain bullet	812	

The time was not taken, as jamming occurred twice, due to a premature explosion. The bullet remained in the barrel, and a bursted case was found in the carrier. It was believed that this accident occurred because the hammer did not rebound, and the point of the pin projecting from the lock-face struck and exploded the cartridge.

Date.	Kind of cartridge.	No. of rounds.	Time.
1883.			
January 6	405-grain bullet	812	45¼ seconds.
January 6	500-grain bullet	816	45¼ seconds.

In the first firing five cartridges missed fire, two exploded on a second trial, three did not. An examination showed that the last three contained what appeared to be fulminate, but it did not explode.

Of five misfires in the second series four operated on a second trial and one on a third. These misfires were not attributed to any defect in the gun.

CONCLUSIONS.

The object of the experiments was to further test the new feed magazine in its adaptability to the use of the service cartridge both with the 500 and 405 grain bullets, and also to test some new features of the gun and carriage above described. The Board in its report of October 11, 1882, on this "feed magazine," when applied to a gun using the English bottle-shaped cartridge, states that it "is all that is claimed for it, and adds very considerably to the value of the gun." In that experiment the gun was fired at various degrees of elevation from 1° to 89°, but in these experiments the gun was fired several times as rapidly as possible with 8 and 9 feed magazines previously filled, and with both kinds of cartridges. The gun was finally dismounted, placed upside down on the staging, and one feed magazine inserted from below, when the gun was fired with as much facility, and the feed worked as well as when placed on top, showing clearly that its action was positive and entirely independent of the force of gravity. No other feed that is known would operate in this manner, and though this is an exaggerated case, and one not likely to occur in service, yet it shows how effectually the cartridge is held from the time it is placed in the feed magazine to its delivery in the carrier block, and how impossible for any clogging or overriding to occur, as is the case at times with other feeds. The premature bursting of the two cartridges in the carrier block before being pushed into the barrel was in nowise due to any imperfect action of the feed magazine, but to the fact that two of the locks were in bad condition and the point of the firing-pin projected beyond the face of the lock before it was released by the cocking-ring, and in the rapid forward movement of the lock the force was sufficient to explode the cartridges. This accident will be effectually avoided in future by holding the firing-pin back by a cam until it reaches the cocking-ring, and when this is done the gun carriage and feed magazine will be so admirably adapted to the requirements they are designed to fulfill that the Board would recommend the gradual replacement of those in service by these new constructions.

T. G. BAYLOR,
Lieutenant-Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with Gatling gun, caliber 0.45 inch, No. 336,

(With drum

	Number of rounds.	Time.	Ammunition.
		1883.	
Barometer, 30.320; thermometer, 47; humidity, 65; wind, 17 miles an hour; p. m.	3	Jan. 3	Frankford ammunition. Powder, 70 grains; bullet, 405 grains.
	3	Jan. 3	......do
	50	Jan. 3	......do
	3	Jan. 3	Frankford solid-head ammunition. Powder, 70 grains; bullet, 500 grains.
	3	Jan. 3	......do
	50	Jan. 3	......do
Barometer, 30.476; thermometer, 28; humidity, 77; wind, 26 miles an hour; a. m.	3	Jan. 4	Frankford ammunition. Powder, 70 grains; bullet, 405 grains.
	3	Jan. 4	......do
	914	Jan. 4	......do
	813	Jan. 4	Frankford solid-head ammunition. Powder, 70 grains; bullet, 500 grains.
Barometer, 30.491; thermometer, 29; humidity, 77; wind, 13 miles an hour; p. m.	102	Jan. 4	Frankford ammunition. Powder, 70 grains; bullet, 405 grains.
	926	Jan. 4	......do
	812	Jan. 4	Frankford solid-head ammunition. Powder, 70 grains; bullet, 500 grains.
Barometer, 30.392; thermometer, 24; humidity, 73; wind, 15 miles an hour; a. m.	3	Jan. 6	Frankford ammunition. Powder, 70 grains; bullet, 405 grains.
	3	Jan. 6	......do
	5	Jan. 6	......do
Barometer, 30.398; thermometer, 24; humidity, 73; wind, 15 miles an hour.	812	Jan. 6	......do
	816	Jan. 6	Frankford solid-head ammunition. Powder, 70 grains; bullet, 500 grains.
	5,324		

at Sandy Hook, N. J., from January 3 *to January* 6, 1883.

feed.)

Elevation.	Direction of wind as regards line of fire.	Time of firing.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
° ′		*M. s.*	
1 20	From front and right.	....	Fired at 500-yard target. Sighting shots.
1 15		....	Do.
1 15		02½	Fired at 500-yard target. Gun aimed 5′ to right of left-hand bull's-eye. Target No. 1.
1 20		....	Fired at 500-yard target. Sighting shots.
1 15		....	Do.
1 15		01½	Fired at 500-yard target. Gun aimed at right-hand bull's-eye. Target No. 2.
4 00	From rear and right.	....	Fired at 1,000-yard target. Sighting shots.
3 50		....	Do.
....		1 03½	Fired into sand butt for rapidity. Two cartridges dropped from drum in handling; 1 missed fire. Cartridge afterwards opened and no fulminate found. Gun worked well.
....		54½	Fired into sand butt for rapidity. Gun worked well.
....	From rear and slightly left.	04	Fired into sand butt. Gun dismounted from carriage and placed on staging upside down, so as to place feed-case at an angle of 180° from its normal position. Gun worked well.
....		1 05	Fired into sand butt for rapidity. Gun worked well. 3 cartridges dropped from drum in handling; 1 miss fire. Cartridge opened and no fulminate found.
....		....	Fired into sand butt for rapidity. In firing this lot gun jammed at 27½ seconds, 5th feed-drum; gun was opened and cartridge-case found exploded and jammed in carrier-block, and bullet belonging to same in barrel No. 10. Bullet and exploded case removed; remaining cartridges in this drum feed case fired and time not taken. Firing resumed with the 3 remaining drums and gun jammed at 2d case after 7½ seconds' time; gun opened and exploded cartridge shell found in carrier-block and its bullet in barrel No. 9. No further trouble with remaining cartridges in this case or case No. 8. One miss fire. Cartridge examined and found to contain no fulminate.
3 50		....	Fired at 1,000 yard target. Sighting shots.
3 30		....	
4 00		....	
....		45½	Fired into sand butt for rapidity. Five miss fires. Two exploded on 2d trial and three did not; these last 3 cartridges cut open and found what looked to be fulminate, but on trial it would not explode.
....		45½	Fired into sand butt for rapidity. 5 miss fires; 4 went on 2d trial and 1 on 3d; 3 dropped from cases in handling.
			In firing for rapidity the drum feed cases were placed in a box and just to the left of the gun, requiring one man to hand them to the expert who turned the crank and placed the feed-cases in position, another man removing the cases as fast as empty and placing them on the ground.

PLATE I.

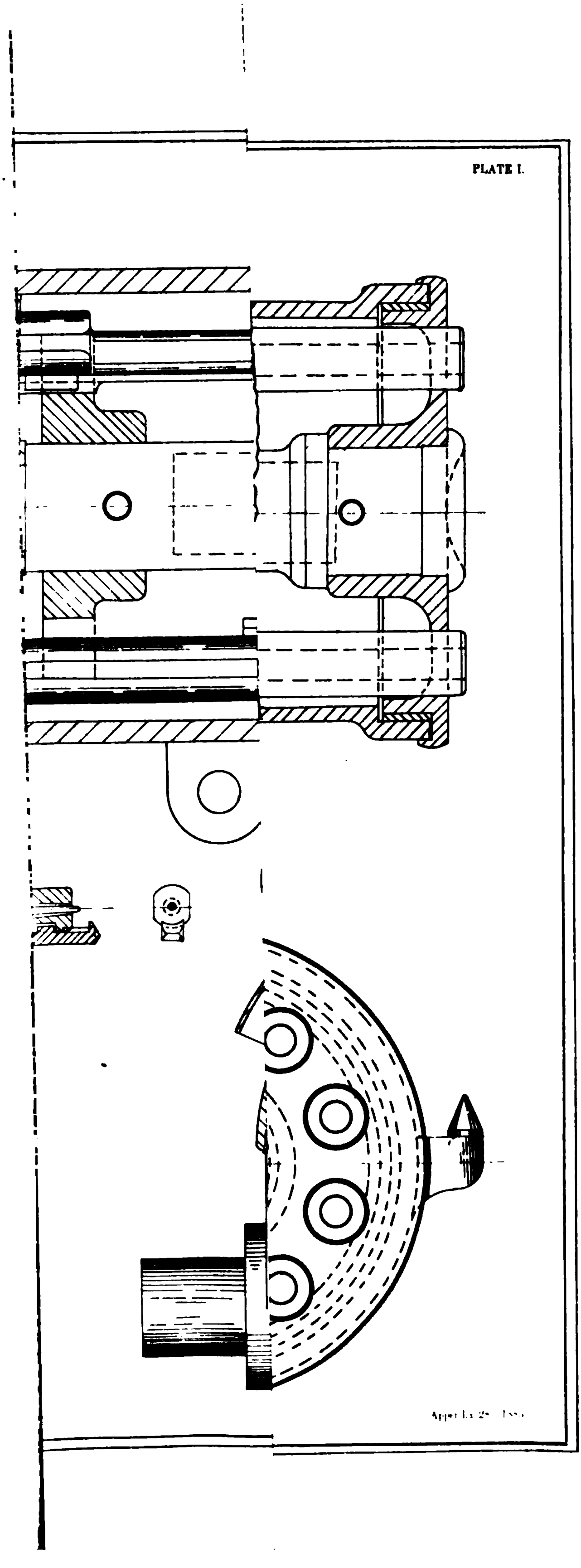


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PLATE II.

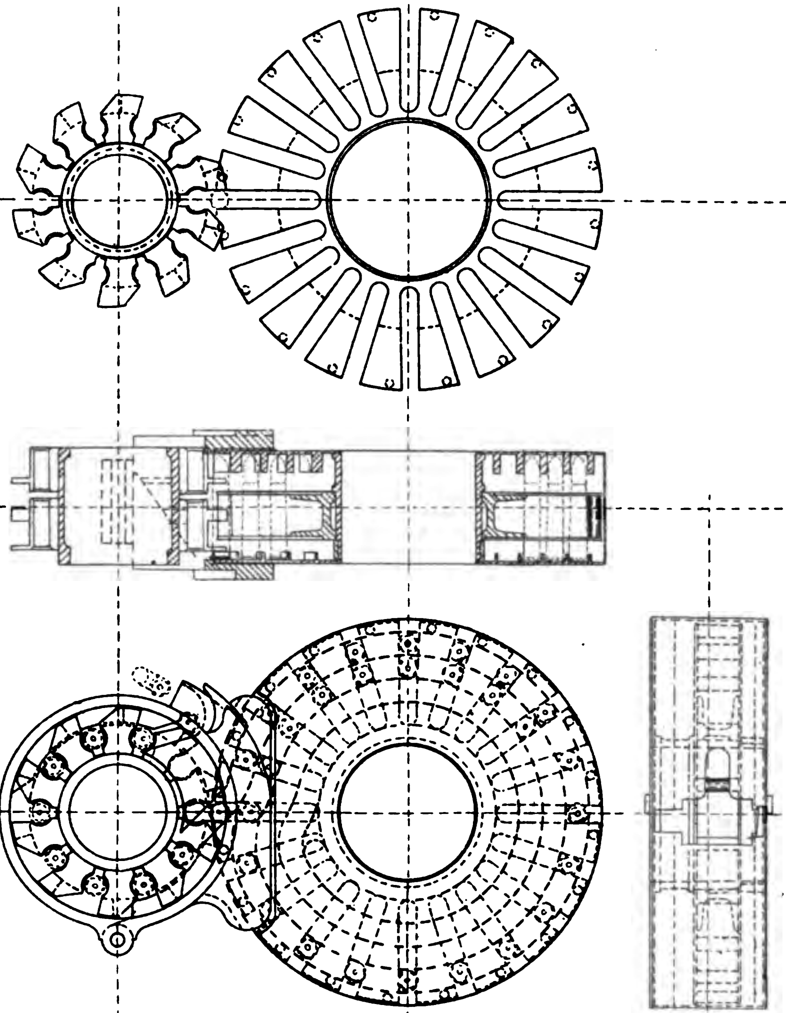

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PLATE III.

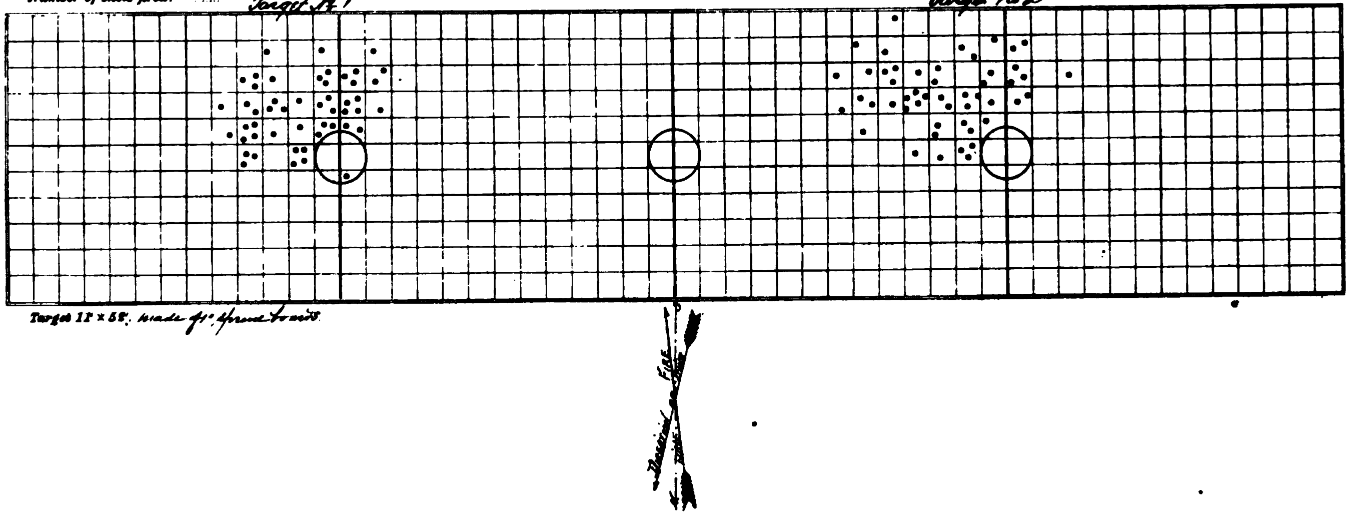
TARGET RECORD OF Gatling Gun Cal 0".45 #336

January 3/83 AT SANDY HOOK, N. J.

Target 500 yards from Gun.

Number of shots fired: 50 each target

Number of hits: 50 each target



Target 12' x 58'; made of 1" spruce boards.

Wind 17 miles per hour.

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APPENDIX 29.

TRIAL OF EIGHT-INCH MUZZLE-LOADING CONVERTED RIFLE NO. 7, BREECH INSERTION, WITH CHILLED PROJECTILES AGAINST ARMOR PLATES.

(11 plates.)

This trial was made under instructions of the Chief of Ordnance given in the fourth indorsement dated July 18, 1882, on Ordnance Office file No. 5333 of 1881. Its principal objects were twofold:

1st. To fix the proper degree of chill to be given to 8-inch shot.

2d. To ascertain their penetration into wrought-iron armor at 1,000 yards. The reduction of charge for a certain reduction of velocity, the applicability of formulæ used for calculating penetration of armor, and any other incidental questions that might arise in the course of the experiments, were to be investigated.

1.—PROPER DEGREE OF CHILL.

The projectiles used were Butler chilled shot, ordered from West Point and South Boston foundries. They differed in form from the ordinary projectiles in having a band turned down at the junction of the head and body to the proper diameter of 7.95 inches, after which a slight reduction of diameter occurred, the sabot having the same diameter as the turned band. Ordinarily the diameter of the body is 7.95 inches throughout, but this change was made to diminish the turned surface and reduce the wear of the lathe tool. The South Boston shot were not so deeply chilled as those received from the West Point foundry. Plate I shows the depth of chill in each case.

The plate target, 12 inches thick, was composed of three 4-inch plates of wrought iron. Each plate was made by combining seven 1-inch plates, bringing them to a welding heat and reducing them by rolling to a single plate 4 inches thick. The quality of the iron is shown by the subjoined tests:

Test for tenacity of three specimens of wrought iron, No. 1 being taken from front plate, No. 2 from middle plate, and No. 3 from rear plate of iron target.

Specimen number.	Diameter of specimen.	Area of broken section.	Breaking weight.	Logarithm of area.	Logarithm of breaking weight.	Tenacity.	Remarks.
	Inch.	*Inch.*	*Pounds.*			*Pounds.*	
1 T	0.6515	0.3028	15,840	$\bar{1}.5228787$	4.1997552	47,520	Fibrous.
1 T	0.6515	0.2799	15,020	$\bar{1}.5228787$	4.1766699	45,060	Do.
1 T	0.6516	0.3127	14,700	$\bar{1}.5228787$	4.1673178	44,100	Do.

The plates 6 by 12 feet in size were assembled by 12 bolts with countersunk heads, which passed through a 24-inch oak backing and a wrought-iron plate 1 inch thick. The arrangement is shown with such full detail in Plate II as to render further description unnecessary. The thickness of this target was such as to render perforation impossible with the ordinary charge at 1,000 yards, as it was deemed that a severer test would be given to the projectiles if they were compelled to give up all their energy than if only a portion of it were absorbed, and that the proper degree of chill could best be determined in this way.

The experiments.

The gun used had been fired 332 rounds before these experiments were undertaken, so that data for making preliminary calculations were at hand. The mean weight of the projectiles used was 183 pounds, and many charges of 35 pounds of hexagonal powder, denominated by the letters E V J, had been fired. The instrumental velocity at 110 feet, with projectiles weighing 183 pounds, gave, as a mean of five results, 1,396 feet. An application of Bashforth's and Hélie's formulæ showed that the corresponding remaining velocity at 1,000 yards would be about 1,215 feet, and that the initial velocity was 1,403 feet. In order to insure striking the target at a determinate point, it was placed at a distance of 200 yards from the piece and the reduction of initial velocity was calculated. It was found by the analytical methods used that an initial velocity of 1,248 feet would give at 200 yards the terminal velocity 1,215 feet required. The first question that presented itself was as to the reduction of charge required to give an initial velocity of 1,248 feet, when the 35-pound charges previously used gave 1,403 feet. Two formulæ were tried to ascertain this point. The first results from the formulæ given by Colonel Benton on page 387, Ordnance and Gunnery, and is

$$p'=\left(\frac{V'}{V}\sqrt{p}\right)^2$$

In which (p) represents the known weight of charge.
V represents the corresponding velocity.
V' represents the desired velocity.
p' represents the weight of charge corresponding to V'.

The second, derived from formulæ used in the French service, is given in the "Manuel d'Artillerie," by Lieut. H. Le Barzic, page 171:

$$p'=p-\frac{p}{n},$$

$$V'=V-\frac{V}{2n}.$$

In which p, V, p', and V' are the same as above, and $\frac{1}{n}$ the fraction by which the charge varies. For the purpose to which these formulæ were applied n may be eliminated by combining the two equations, and we have for the value of the reduced charge

$$p'=p\left(\frac{2V'-V}{V}\right)$$

In both cases p, V, and V' are known.

An application of these formulæ gave the results tabulated below:

Charge used. p.	Corresponding initial velocity. V.	Required initial velocity. V′.	Reduced charge corresponding V′. p'.	
			$p' \cdot \left(\frac{V'}{V.}\sqrt{p}\right)^2$	$p' - p\left(\frac{2V'-V}{V}\right)$
Pounds. 35	*Feet.* 1,403	*Feet.* 1,248	*Pounds.* 27.8	*Pounds.* 27.3

A mean of the deduced weights, 27 pounds 9 ounces, was taken, but the resulting velocities were in all cases too high. They were irregular, varying with the same charge from 1,251, within 3 feet of the velocity required, to 1,307, exceeding it by 59 feet. The charges were reduced to 26 pounds 8 ounces and the results were satisfactory. There has not been enough firing with reduced charges from this gun to fairly estimate the accuracy of the formulæ, but the indications are that for a diminution of nearly $\frac{1}{5}$ the weight of the charge they gave only approximate results. A wooden target was placed at the side of the plate and at the same distance from the piece. Preliminary shots were fired against it to determine the elevation of the piece and remaining velocity of the shot. The efforts to determine the remaining velocity were unsuccessful.

Incidents of the trial.

First shot at plate. Round No. 352. Plate III. West Point projectile fired at angle of 35°. Remaining velocity, 1,261 feet. An indentation of 5.75 inches deep was made in the plate, and the shot broke up into one large and several small fragments.

Second shot at plate. Round No. 355. Plate IV. South Boston projectile fired at an angle of 35°. Remaining velocity, 1,233 feet. An indentation of 5.06 inches deep was made in plate, and the shot broke into many small fragments.

Third shot at plate. Round No. 356. Plate V, Fig. 1. West Point projectile fired at an angle of 15°. Remaining velocity, 1,201 feet. The shot penetrated the plate to a depth (measured vertically) of 9 inches and was cracked, but the pieces did not separate, and the projectile, after having molded its form as far as it penetrated the plate, rebounded.

Fourth shot at plate. Round No. 357. Plate V, Fig. 2. South Boston projectile, fired at an angle of 15°. Remaining velocity, 1,190.5 feet. The penetration was 8.7 inches, and the shot was cracked, but not so much as that used in the preceding shot.

Fifth shot at plate. Round No. 358. Plate VI, Fig. 1. West Point projectile, fired normally at plate. Remaining velocity, 1,219 feet. The penetration was 9.7 inches. The head of the shot snapped off near its junction with the body, and the latter was cracked.

Sixth shot at plate. Round No. 359. Plate VI, Fig. 2. South Boston projectile, fired normally. Remaining velocity, 1,207.5 feet. The penetration with this shot was 10.7 inches, 1 inch more than the above, although the remaining velocity was less. The shot, however, did not break, but, as Plate VI, Fig. 2, shows, the only injury was a crack developed in the body.

Seventh shot at plate. Round No. 368. Plate VII, Fig. 1. West Point projectile, fired normally. Remaining velocity, 1,246.5 feet. The penetration was 9.59 inches. The head was, as in the fifth round, where the shot was fired in the same way, broken off and the body split into four sections.

Eighth shot at plate. Round No. 369. Plate VII, Fig. 2. South Boston projectile, fired normally. Remaining velocity, 1,220.9 feet. Penetration was 10.3 inches. The body cracked, the head remaining in position.

Ninth shot at plate. Round No. 370. Plate VIII, Fig. 1. West Point projectile, fired at an angle of 15°. Remaining velocity, 1,213.5 feet. The penetration was 9.25 inches. The point and head of the projectile were badly cracked, and the projectile itself remained sticking in the plate.

Tenth shot at plate. Round No. 371. Plate VIII, Fig. 2. South Boston projectile, fired under an angle of 15°. Remaining velocity, 1,214.5 feet. The projectile penetrated 9.37 inches and rebounded. Although the body was cracked, the head was not broken as in shot No. 9.

Plate IX shows an elevation of the target with the position of the points aimed at and the points struck, as well as the form of the indentations made.

It will be seen from the incidents above narrated that two series of shots were fired with each projectile at different angles, and efforts were made to have the attendant circumstances as nearly similar as possible, so that correct comparisons could be made. It appears that when the line of fire was normal to the plate, in which case the projectiles would more completely give up their energy, the degree of chill in the West Point projectiles was too great, and in consequence the head broke off. The shallower chill of the South Boston projectiles is deemed the best, and it is recommended that it shall be made the standard for 8-inch muzzle-loading projectiles of chilled cast iron made hereafter.

2.—PENETRATION INTO WROUGHT-IRON ARMOR.

The plate target 8 inches thick was composed of two 4-inch plates of wrought iron each made as those previously described. The following table shows their physical characteristics:

Specimen No. 4, 1 T.		
Diameter of specimen	inch	0.6515
Area of broken section		0.2743
Breaking weight	pounds	16,890
Logarithm of area		$\bar{1}$.5228787
Logarithm breaking weight		4.2276296
Tenacity in pounds		50,670
Constitution of plate, fibrous.		

The plates, 6 feet by about 12 feet in size, were assembled and backed as shown in Plate X.

The charge of 26.5 pounds, which had given the required terminal velocity of 1,215 feet in the firing last carried on, was adopted for this series. Owing to the greater humidity and heavier atmospheric pressure, velocities obtained were not so great as desired. The highest terminal velocity was 1,198 feet, the lowest 1,161.5 feet, and the mean was 1,180.8 feet. Analysis shows that this terminal velocity would ensue where the mean muzzle velocity of 1,403 feet is used as a basis of calculation at a distance of 1,200 yards. The results obtained in the experiments about to be described must then be considered as those of firing against eight inches of armor at a distance of 1,200 yards.

All the shots of this series were plotted upon the same plate hereto appended and marked Plate X.

Incidents of the trial.

First shot. Round No. 383. West Point projectile fired at an angle of 35°. Remaining velocity, 1,161.5. This shot was fired under a high angle for the purpose of comparing its effect against an 8-inch plate with that which resulted when the heavier plating was used. The shot was broken into fragments, and the indentation, 3.75 inches, was 2.0 inches less than the first one obtained with the 12-inch plate. The remaining velocity, however, was 100 feet less than in the first case, so that no comparison could be made, and as the projectiles fired at this angle were entirely destroyed no further firing was carried on at such an inclination.

Second shot. Round No. 384. South Boston projectile fired at an angle of 15°. Remaining velocity, 1,197 feet. This shot perforated the first plate and penetrated the second, bending thin layers of it, and carrying them about 4.62 inches into the backing. The projectile rebounded; the body was cracked, but the head remained intact.

Third shot. Round No. 385. West Point projectile fired at an angle of 15°. Remaining velocity, 1,198 feet. This shot perforated both plates and passed in the backing a distance of 12.12 inches. It struck the plate, however, at a point that had been previously indented by the first round. The body of the projectile was cracked and the head entirely broken up.

Fourth shot. Round No. 386. South Boston projectile fired normally. Remaining velocity, 1,185 feet. The shot perforated both plates and entered 5.75 inches into the backing. The body was cracked; the head was uninjured. The shot remained in the target.

Fifth shot. Round No. 387. South Boston projectile fired normally. Remaining velocity, 1,164.5 feet. The shot perforated both plates and entered the backing 4 inches. The body was cracked.

Sixth shot. Round No. 388. South Boston projectile fired normally. Remaining velocity, 1,187.5 feet. A charge of 2 pounds of musket powder was inserted in the core cavity, and the force of impact caused it to explode; both plates were perforated; the body was cracked and the head forced 13.5 inches into the backing.

3.—COMPARISON OF PENETRATIONS AND PERFORATIONS OBTAINED WITH CALCULATED RESULTS.

There are no formulæ extant for the penetration of projectiles into firmly backed plates, those given in the text-books being intended for plates unbacked. To ascertain if there be any relation between the results obtained by calculation and the results obtained in firing against the firmly backed plates used in the first series of shots described, the following formulæ were tried:

W. H. Noble:

$$S=1.6\sqrt{\frac{E}{2.53}}$$

Andrew Noble:

$$S=1.5\sqrt{\frac{E}{3.18}}$$

English formula for plates from 10 to 20 inches thick:

$$s=2.035\sqrt{\frac{E}{0.86}}$$

In which (s) is the thickness of plate that will be penetrated by a shot having on impact an energy in foot-tons E for each inch of its circumference.

Maitland:

$$s=\frac{E}{4.733\pi r^2}$$

In which E=the total energy in foot-tons on impact and (r) is the radius of the projectile in inches.

For the first three formulæ:

$$E=\frac{WV^2}{2g\times 2240\times \pi D}$$

In which

W=weight of projectile=183 pounds.
D =its diameter=7.95 inches.
V =its velocity on impact.
π =3.14159.

Hence,

$$E=\frac{183}{2\times 32.16\times 2240\times 3.14159\times 7.95}V^2$$

Dividing the above expression by 2.53, we have for conveniently calculating W. H. Noble's formula,

$$s=\frac{\text{Log } V^2+\bar{5}.30522}{1.6}$$

For Andrew Noble's formula divide by 3.18,

$$s=\frac{\text{Log } V^2+\bar{5}.20391}{1.5}$$

For the thick plate formula divide by 0.86,

$$s=\frac{\text{Log } V^2+5.77184}{2.035}$$

For Maitland's formula,

$$E=\frac{WV^2}{2\times g\times 2240\times \pi r^2}=\frac{183}{2\times 32.16\times 2240\times 3.14159\times 3.975^2};\ V^2$$

dividing by 4.733 we have, and for convenience in calculation:

$$s=\text{Log } V^2+\bar{6}.73287$$

The table given below shows the results obtained with the shots fired normally at the 12-inch plate and the calculated results by the above formulæ.

Number of shot.	Number of round.	Remaining velocity.	Actual penetration.	Calculated penetration—inches.			
				W. H. Noble's formula. $S=1.6\sqrt{\frac{E}{2.53}}$	Andrew Noble's formula. $S=1.5\sqrt{\frac{E}{3.18}}$	Thick plate formula. $S=2.035\sqrt{\frac{E}{0.86}}$	Maitland's formula. $S=\frac{E}{4.733\pi r^2}$
		Feet.	*Inches.*				
5	358	1,219	9.7	8.380	8.226	9.1	8.03
6	359	1,207.5	10.7	8.282	8.162	8.935	7.88
7	368	1,212.8	9.6	8.327	8.210	9.53	7.952
8	369	1,220.9	10.	8.397	8.283	9.0338	8.058

From the above table it appears that the first two formulæ give results that are nearly the same and about 20 per cent. less than the actual penetration, while the third formula gives results more nearly in accord with the experimental penetration and about 8 per cent. less. Maitland's formula gives the lowest results.

For perforation the first two formulæ were compared with the experimental results and tabulated.

Number of shot.	Number of round.	Thickness of plate.	Perforation, actual.	By W. H. Noble's formula. $S=1.6\sqrt{\frac{E}{2.53}}$	By Andrew Noble's formula. $S=1.5\sqrt{\frac{E}{3.18}}$
2	384	8 inches.	Complete.	8.19	8.07
3	385			8.20	8.19
4	386			8.09	7.95
5	387			7.91	7.78
6	388			8.03	7.90

From which it appears that the first formula gives results that are suitable for application with this gun and projectile. The following table is calculated for various ranges by means of W. H. Noble's formula.

Table giving velocity, energy, and penetration of the 8-inch muzzle-loading converted rifle, at various ranges.

[Weight of charge, 35 pounds E. V. M. powder; density, 1.750; granulation, 72. Weight of chilled projectile, 183 pounds.]

Range.	Velocity.	Total energy (foot-tons). $\frac{WV^2}{2g\times 2,240}$	Energy per inch of shot's circumference (foot-tons). $\frac{WV^2}{2\times g\times 2,240\times \pi D}$	Penetration into plating. W. H. Noble. $1.6\sqrt{\frac{E}{2.53}}$
Yards.	*Feet.*			*Inches.*
0	1,403	2,500	100	9.96
500	1,302	2,155	86	9.08
1,000	1,214	1,871	75	8.31
1,500	1,136	1,638	66	7.65
2,000	1,069	1,452	58	7.08
2,500	1,018	1,317	53	6.67
3,000	980	1,219	49	6.36

The accompanying Plate XI shows the appearance of the backing after the 8-inch face plates were removed, and the photograph No. 5 shows the same thing.

Photograph No. 6 shows a view from the left, and photograph No. 7 a front view of the 8-inch target.

SUMMARY.

1st. The results with the shallow chill were best.

2d. The shot which did not perforate the plate rebounded, indicating that the radius of the head (1.25 of the diameter) should be increased to 1.5.

3d. The two formulæ for the reduced charge give nearly the same results, and are only approximate.

4th. A bursting charge is ignited by impact, and even when small increases the effect of penetration.

5th. The formula of W. H. Noble for penetration is applicable to these guns and projectiles.

CONCLUSION.

The result of these experiments shows that the power of this gun is sufficient to penetrate any iron-clad with a wrought-iron armor not exceeding 8 inches, which will include more than half of the armored vessels of the world, and hence that for certain places on our sea-coast, where the depth of water will only admit of the passage of vessels of light draught and of comparatively thin armor, this gun is adequate for their defense.

For the Board.

T. G. BAYLOR,
Colonel of Ordnance, President.

Record of firing with 8-inch muzzle-loading rifle No. 7, breech insertion,

	Number of fire.	Time.	Powder.			Projectile.		Elevation.	Pressure, pounds per square inch of bore.
			Kind.	Weight.		Kind.	Weight.		
		1882.		Lbs.	Oz.		Lbs.		
Barometer, 30.101; thermometer, 61; humidity, 93; wind, 8 miles an hour.	349	Nov. 1	Du Pont's Hexagonal E. V. J. No. 6. Density, 1.750. Granulation, 72. (Rounds 358, 359, 368, and 369 out of same barrel.)	27	9	Butler chilled shot, West Point Foundry (new.)*	183	—5′	23,500
	350	Nov. 1		27	9		183	0	26,500
Barometer, 30.105; thermometer, 66; humidity, 58; wind, 8 miles an hour,	351	Nov. 1		27	9		183	5′	32,500
	352	Nov. 1		27	4		183	7½′	27,500
Barometer, 30.321; thermometer, 56; humidity, 57; wind, 9 miles an hour.	353	Nov. 2		27	0		183	10′	28,000
	354	Nov. 2		27	0		183	10′	30,000
Barometer, 30.336; thermometer, 56; humidity, 45; wind, 20 miles an hour.	355	Nov. 2		27	4	Butler chilled shot, South Boston Foundry (new).†	183	10′	27,500
Barometer, 30.457; thermometer, 48; humidity, 56; wind, 2 miles an hour.	356	Nov. 3		26	0	Butler chilled shot, West Point Foundry (new).	183	17½′	23,500
Barometer, 30.399; thermometer, 46; humidity, 54; wind, 3 miles an hour.	357	Nov. 3		26	0	Butler chilled shot, South Boston Foundry (new).	183	17½′	24,500
Barometer, 30.406; thermometer, 46; humidity, 68; wind, 26 miles an hour.	358	Nov. 4		26	8	Butler chilled shot, West Point Poundry (new).	183	5′	26,000
Barometer, 30.392; thermometer, 46; humidity, 63; wind, 18 miles an hour.	359	Nov. 4		26	8	Butler chilled shot, South Boston Foundry (new).	183	7′	25,000
Barometer, 30.343; thermometer, 42; humidity, 65; wind, 15 miles an hour.	360	Nov. 6		26	8	Butler chilled shot, South Boston Foundry (new).	183	10′	22,000
	361	Nov. 6		26	8	Butler chilled shot, West Point Foundry (new).	183	10′	25,500
	362	Nov. 6		26	8	Butler chilled shot, South Boston Foundry (new).	183	10′	23,500
	363	Nov. 6		26	8	Butler chilled shot, West Point Foundry (new).	183	10′	26,500
Barometer, 30.306; thermometer, 46; humidity, 61; wind, 12 miles an hour.	364	Nov. 6		26	8	Butler chilled shot, South Boston Foundry (new).	183	10′	22,000
	365	Nov. 6		26	8	Butler chilled shot, West Point Foundry (new).	183	10′	24,500
	366	Nov. 6		26	8	Butler chilled shot, South Boston Foundry (new).	183	10′	24,500
	367	Nov. 6		26	8	Butler chilled shot, West Point Foundry (new).	183	10′	23,500
Barometer, 30.285; thermometer, 46; humidity, 68; wind, 8 miles an hour.	368	Nov. 8		26	8		183	16′	24,500
Barometer, 30.263: thermometer, 48; humidity, 71; wind, 6 miles an hour.	639	Nov. 8		26	8	Butler chilled shot, South Boston Foundry (new).	183	10′	24,500

Length of West Point shot, 19⅛″.

† Length of South Boston shot, 19$\frac{1}{16}$.

at Sandy Hook, N. J., from November 1, 1882, *to January* 26, 1883.

Instrumental velocity at 110 feet from muzzle.	Recoil.	Direction of wind.	Velocity with Schultz chronoscope at 600 feet from muzzle.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Feet.	*Feet.*		*Feet.*	
1, 251	2.00	From front and right.	....	Fired at 200-yard wooden target.
1, 263	1.92		....	
1, 307	2.00	From rear and slightly left.	....	
1, 291	......		....	Fired at 200-yard iron target. Target at an angle of 35° from normal. Entire target driven back 2″.6 and thrown out of plumb. Shot broke up. Penetration, 5″.75 (See sketch marked A.)
1, 264	2.08	From rear and slightly right.	....	Fired at 200-yard wooden target.
1, 262	......		1, 249	
1, 276	......	From rear and right.	....	Fired at 200-yard iron target. Target at an angle of 35° from normal. Left-hand side of target driven back 5″.75, not thrown out of plumb. Shot broke up. Penetration, 5$\frac{1}{16}$″. (See sketch marked B.)
1, 229	......	From front and right.	....	Left-hand side of target driven back 2″.5. Shot did not break up, but cracked. Penetration, 9″. See sketch marked C.) Fired at 200-yard iron target. Target at an angle of 15° from normal.
1, 217	......	From front and slightly right.	....	Shot did not break up, but cracked. Penetration. 8″.7. (See sketch marked D.)
1, 247	......	From rear and left.	....	Shot broke in two and cracked. Penetration, 9″.7. (See sketch marked E.) Fired at 200-yard iron target. Target normal.
1, 235	......		....	Shot did not break up, but cracked. Penetration, 10″.7. (See sketch marked F.)
			Velocity with Boulengè chronograph No. 109 at 600 feet from muzzle.	
1, 216	2.25		1, 165	Fired at 200-yard wooden target for velocities.
1, 248	2.25		1. 225	
1, 243	2.17		1, 205	
1, 249	2.17		1, 210	
			Schultz chronoscope at 600 feet from muzzle.	
1, 226	2.17		Lost.	
1, 241	2.08		1, 174	
1, 244	2.25		1, 188	
1, 233	2.25		Lost.	
1; 240	......		....	Shot broke in two and cracked. Penetration, 9$\frac{3}{16}$″ (See sketch marked G.) Shortly after firing this round small crack was visible, running from indentation made by round 355 downward about 14″.5. (See sketch marked K.) Fired at 200-yard iron target. Target normal.
1, 249	......		....	Shot did not break; cracked. Penetration 10″.8. (See sketch marked H.)

Record of firing with 8-inch muzzle-loading rifle No 7,

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure, pounds per square inch of bore.
		1882.		*Lbs. Oz.*		*Lbs.*		
Barometer, 30.228; thermometer, 51; humidity, 66; wind, 3 miles an hour.	370	Nov. 8		26 8	Butler chilled shot, South Boston Foundry (new).*	183	5′	23,500
Barometer, 30.237; thermometer, 50; humidity, 69; wind, 6 miles an hour.	371	Nov. 9		26 8	Butler chilled shot, West Point Foundry (new).†	183	17′	23,500
		1883.						
A. M.: Barometer, 30.350; thermometer, 28; humidity, 77; wind, 22 miles an hour.	382	Jan. 25	Du Pont's Hexagonal E. V. J. No. 7. Density, 1.750. Granulation, 72.	26 8	Butler chilled shot, South Boston Foundry (new).	182	10′	21,500
	383	Jan. 25		26 8	Butler chilled shot, West Point Foundry (new).	182	9′	20,500
P. M.: Barometer, 30.350; thermometer, 27; humidity, 88; wind, 12 miles an hour.	384	Jan. 25		26 8	Butler chilled shot, South Boston Foundry (new).	182	16′	22,000
	385	Jan. 25		26 8	Butler chilled shot, West Point Foundry (new).	182	5′	23,000
A. M.: Barometer, 30.472; thermometer, 21.5; humidity, 84; wind, 22 miles an hour.	386	Jan. 26		26 8	Butler chilled shot, South Boston Foundry (new).	182	16′	22,000
	387	Jan. 26		26 8	Butler chilled shot, South Boston Foundry (new).	182	3′	20,000
	388	Jan. 26		27 0	Butler chilled shot, South Boston Foundry (new). Shot-core filled with 2 pounds musket powder.	182	9′	22,500

---

*Length of South Boston shot, 19$\frac{1}{16}$.

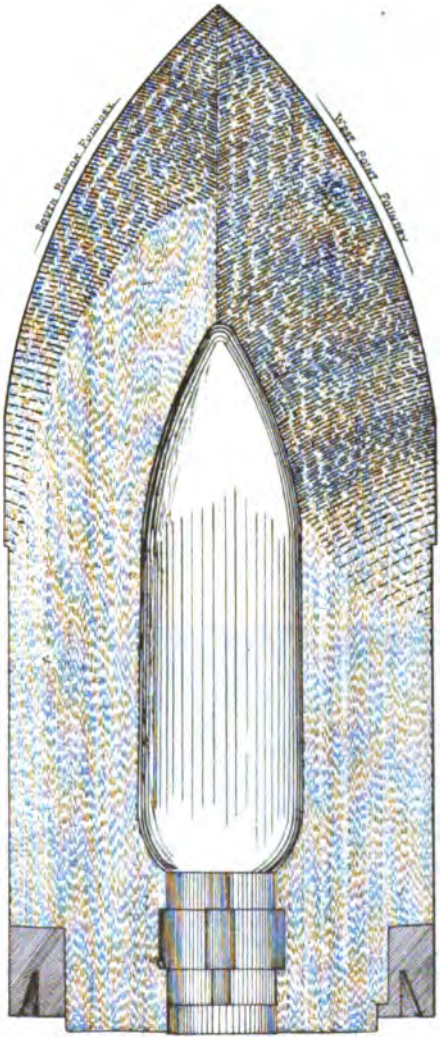
† Length of West Point shot, 19$\frac{1}{8}$″.

breech insertion, at Sandy Hook, N. J., &c.—Continued.

Instrumental velocity at 110 feet from muzzle.	Recoil.	Direction of wind.	Velocity with Schultz chronoscope at 600 feet from muzzle.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Feet.	*Feet.*		*Feet.*	
1, 241	......	From right and front.	....	Fired at 200-yard iron target. Target at an angle of 15° from normal. Shot remained in the target; dislodged by round 371; cracked at point. Penetration, 9″.25. (See sketch marked I.)
			Instrumental velocity at 600 feet from muzzle.	
1, 242	......	From right and slightly rear.	....	Fired at 200-yard iron target. Target at an angle of 15° from normal. Shot did not break up; cracked. Penetration, 9″.37. (See sketch marked J.) Shortly after firing this round small crack visible, running from indentation made by this round downward to that made by round 370. (See sketch marked K.)
1, 228	2. 00	From rear ...	Lost.	Fired at 200-yard wooden target.
1, 187	1. 75		....	Fired at 200-yard iron target. Target at an angle of 35° from normal. Shot broke up in small pieces, which tore away safety butt on left of target, and were found distributed on the sand, the most distant being about 100 yards from the target and on a line about parallel with its face. Left-hand side of target thrown back 1½″, right-hand side thrown forward about 1″, and the entire target thrown slightly to the left. Penetration, 3⅞″. (See sketch marked L.)
1, 224	1. 83		....	Fired at 200-yard iron target. Target at an angle of 15° from normal. Shot did not break up; cracked. Left-hand side of target thrown back 1⅞″, and right side thrown forward same distance. Entire target thrown slightly from left to right. Three angle iron braces on rear of target cracked. Penetration, 12⅝″. (See sketch marked L.)
1, 225	1. 75		....	Shot broke up, pieces remaining in target. Left-hand side of target thrown back 6″.75, right-hand side thrown forward 1⅜″. Entire target thrown to left 2⅝″. One bolt broken and thrown forward. Two pieces of target weighing ¾ and ½ pounds were dislodged by this shot and thrown to the front and left 803 feet and 583 feet, respectively. Considerable flame noticed on target at instant of shot striking same. Penetration, 20½″. (See sketch marked L.)
1, 212	2. 25	From rear and left.	....	Fired at 200-yard iron target. Target normal. Shot remained in target, cracked. Right-hand side of target thrown back 2⅞″, and left side thrown forward ¾″. Right-hand bolt fastening horizontal backing timbers together broke, allowing the two upper timbers to raise about 2″. Two of the wooden braces at rear of target split and upper left-hand brace dislodged. Penetration, 13¾″. (See sketch marked L.)
1, 190	2. 75		....	Shot remained in target, slightly cracked. Right-hand side of target thrown back 5″; left-hand side thrown forward ⅛″; entire target thrown to right 1¼″. This shot developed a crack running from the indentation made by shot downward to bottom of target. Penetration, 12″. Two angle iron braces in rear of target cracked. (See sketch marked L.)
1, 205	2. 42		....	Shot burst in target, the fragments remaining. Left-hand side of target thrown back 2¼″; right side thrown back 2″. Sabot picked up 65 paces in front of target. Penetration, 21½″. Two angle iron braces in rear of target cracked. (See sketch marked L.)

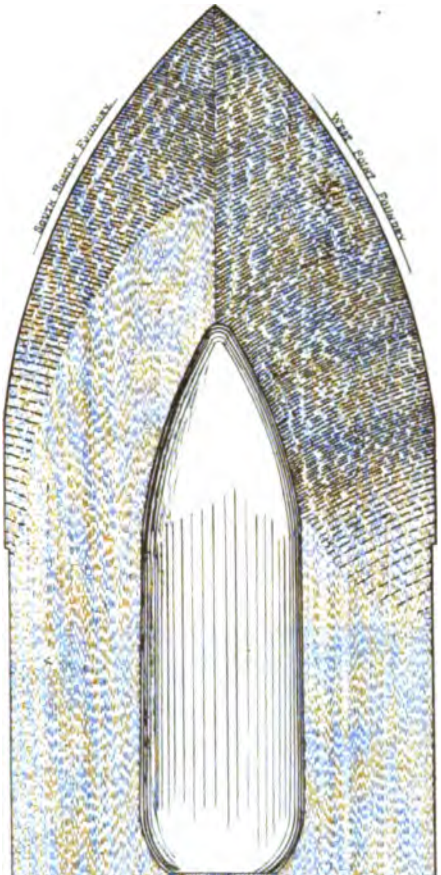
‡ In each round fired at iron target considerable flame noticed on target at instant of shot striking same.

PLATE I.



Appendix 29—1883

PLATE I.



Appendix 29—1883

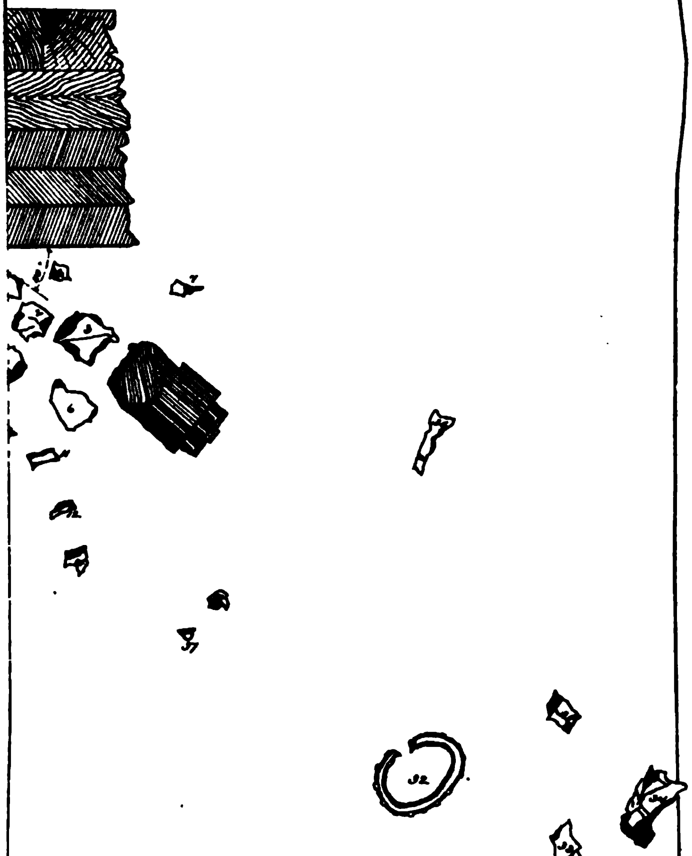
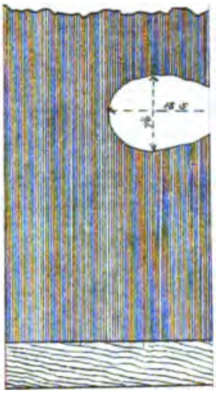


PLATE IV.



1.	1' Left.	0' Short
2.	54' " "	1' Short.
3.	56' " "	2' Short.
4.	56' " "	16' Short
5.	3' " "	2'10" Short.
6.	10' " "	2'10" Short.
7.	3'4" " "	14' Short.
8.	4'7" " "	20' Short.
9.	12' " "	1' Short.
10.	5'3" " "	17' Short.
11.	5'5" " "	18' Short.
12.	8'2" " "	15' Short.
13.	5'5" " "	39 Short.
14.	7'0" " "	39 Short
15.	17' " "	01 Short.
16.	16' " "	15' Short.
17.	3'7" right.	19' Short.
18.	7'10" left.	23' Short.
19.	12' right	11' Short.
20.	7 right.	9' Short.
21.	13' "	3'11" Short
22.	21' " "	33' Short.
23.	19' " "	34' Short.
24.	3' " "	16' Short.
25.	11' " "	14' Short.
26.	19' " "	10' Short.
27.	11' " "	22' Short.
28.	3'6" " "	19' Short.
29.	3'6" " "	30' Short.
30.	1'2" " "	25' Short.
31.	4' " "	23 Short.
32.	3'0" " "	28' Short.
33.	4' " "	39' Short.
34.	10' " "	41' Short.
35.	11'6" " "	36' Short.
36.	18' " "	18' Short.
37.	16' " "	42' Short.
38.	4' " "	76' Short.
39	17' left.	24 Short.
40.	7'9" " "	4' Short
41.	38' right.	34' Short
42.	8'2" left.	30' Short
43.	4'7" " "	3'4" Short.
44.	37' right.	2' Left.
45.	17' Left.	17' Short
46.	5' right.	21' Short.
47.	7'4" left.	4' Short
48.	87' right.	36' Short.
49.	108' right.	97' Short.
50.	84' right	44' Short.
51.	95' right.	50' Short

PLATE V.

Fig. 1.

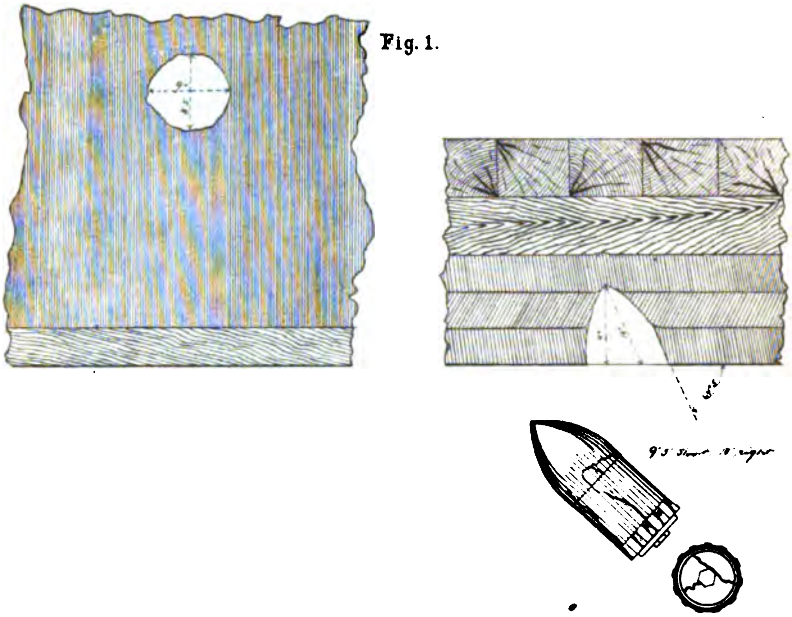
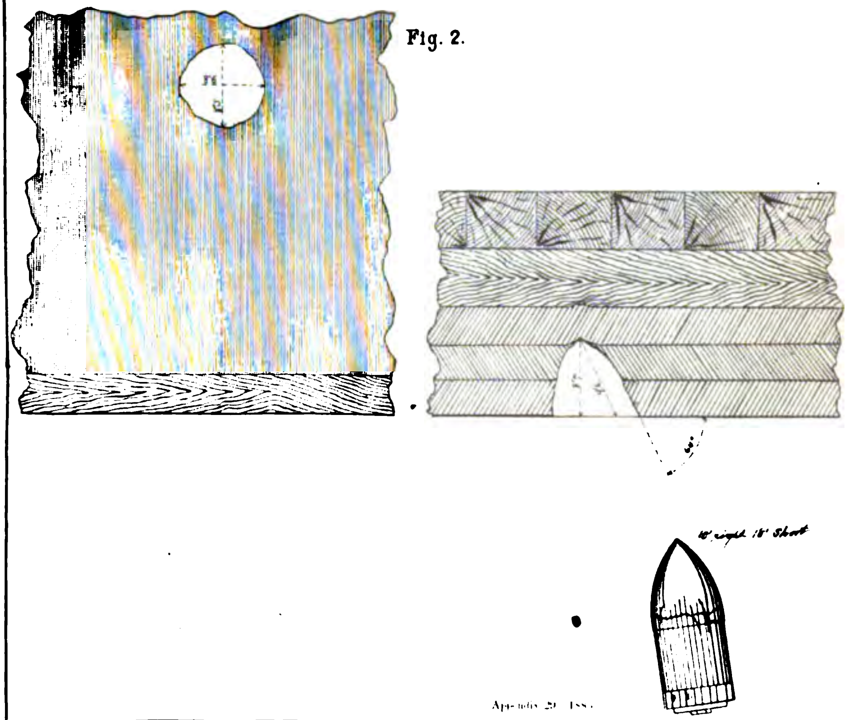


Fig. 2.



Appendix 29. 188

Fig. 1.

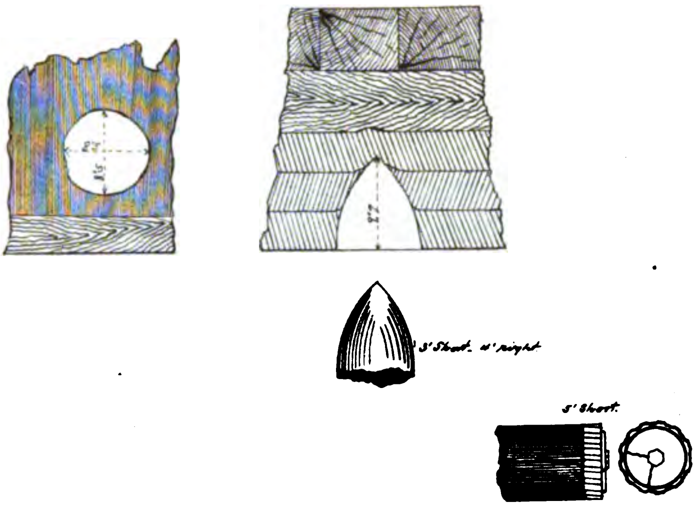


Fig. 2.

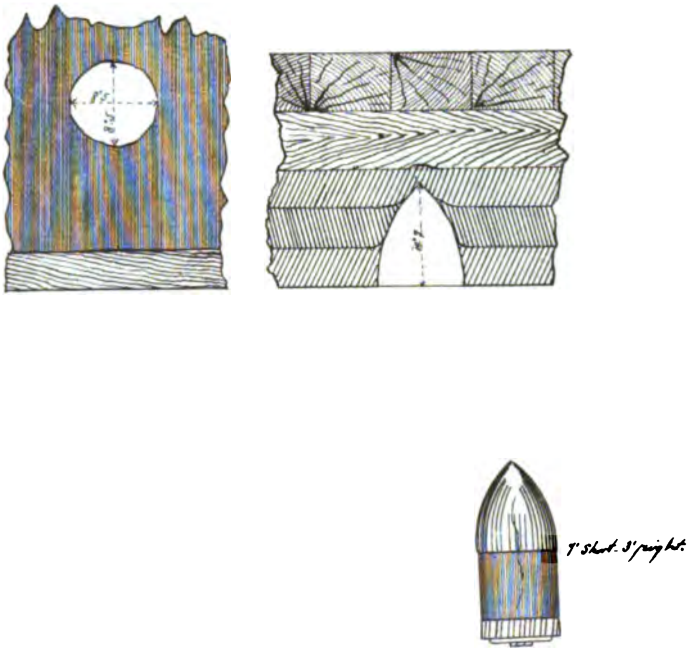
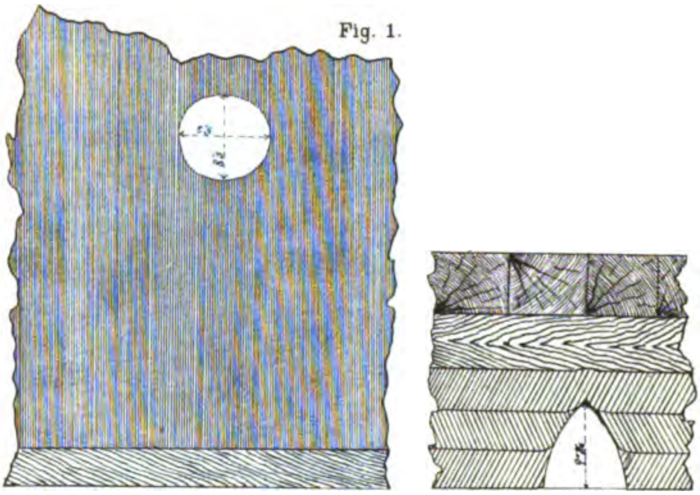


PLATE VII.

Fig. 1.



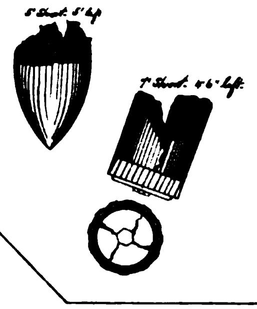
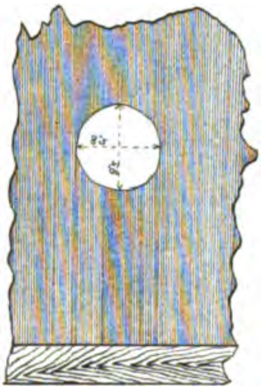


Fig. 2.



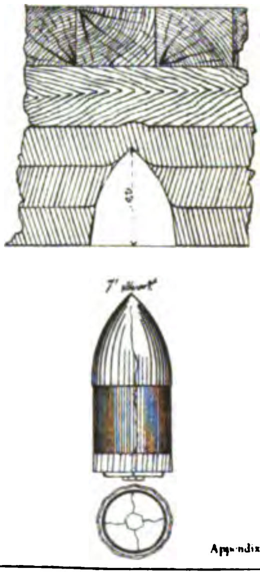


PLATE VIII.

Fig. 1.

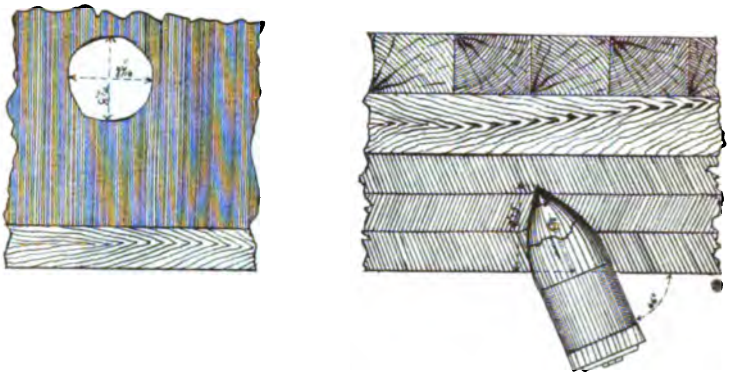
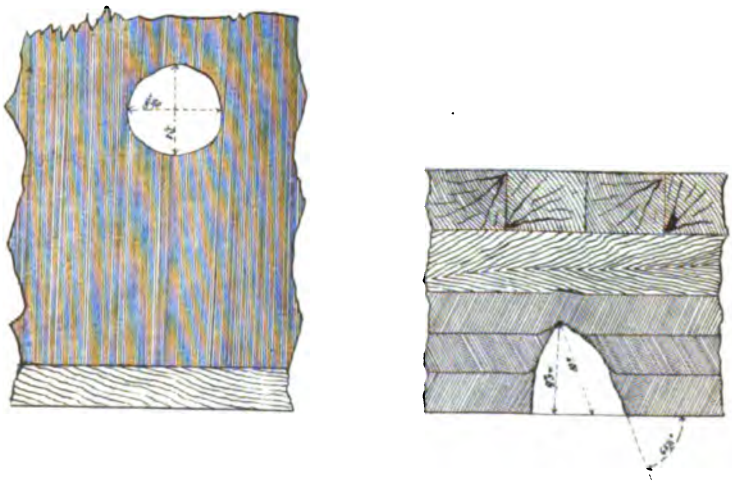
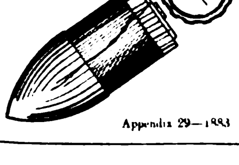


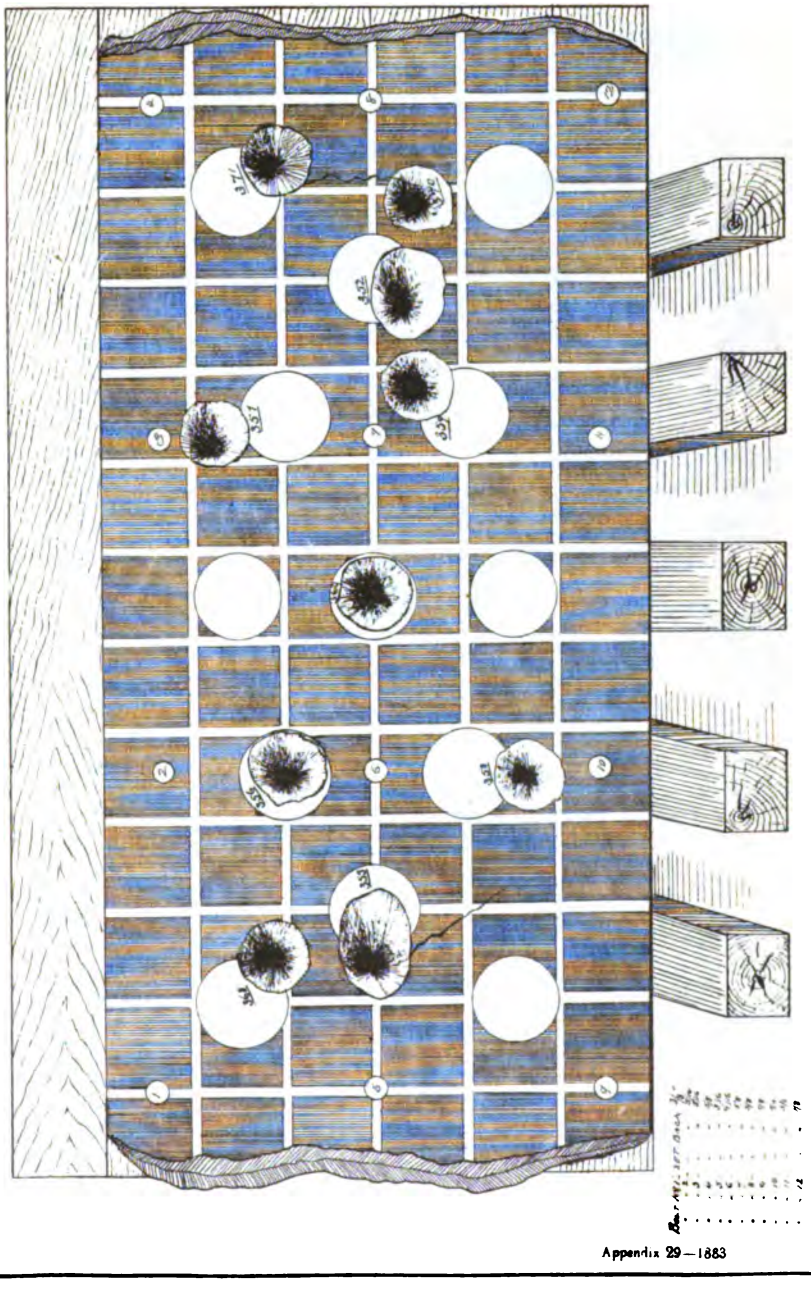
Fig. 2.





Appendix 29—1883

PLATE IX.



Appendix 29—1883

TIMBER BACKING BEHIND IRON TARGET.

Nos. 2 & 5 Points of Shot

Nos. 1, 3, 4, 6, 7, 8, 9, 10 & 11 Pieces of Target plate

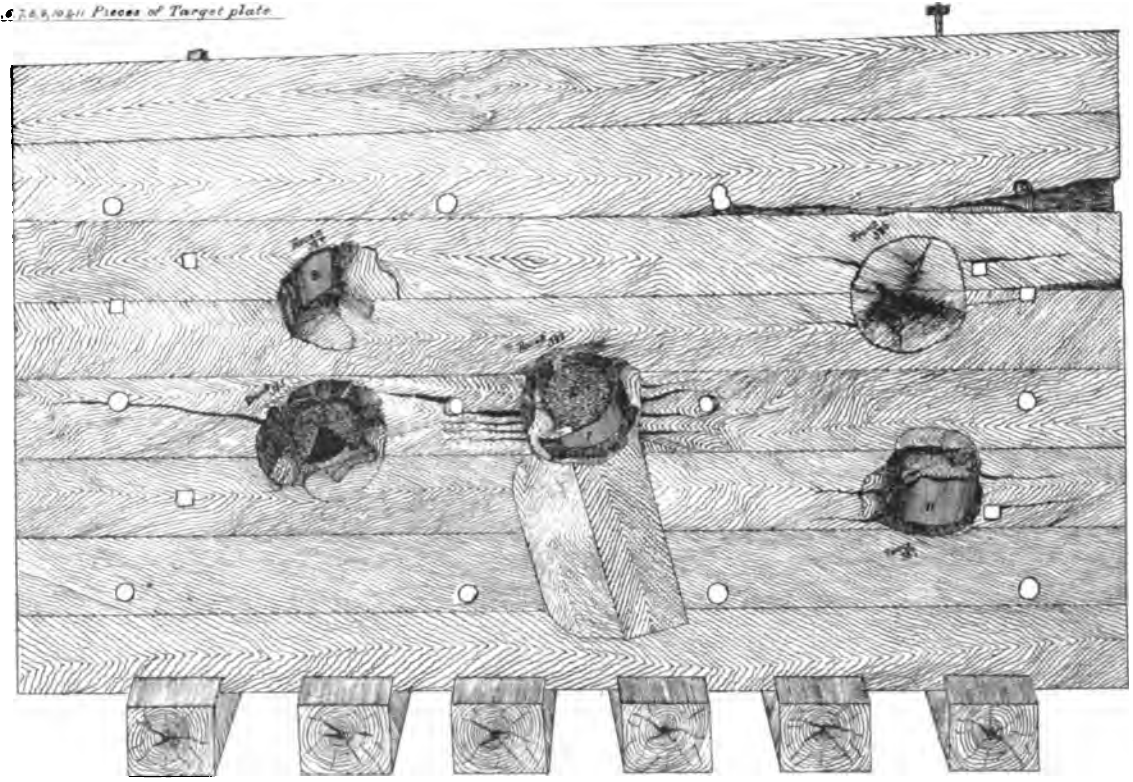
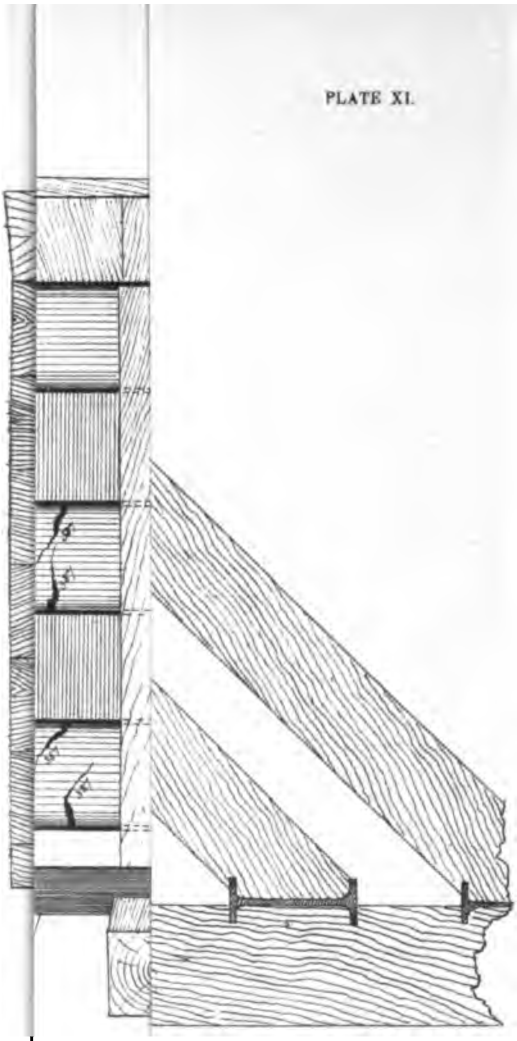
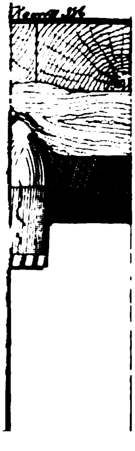


PLATE XI.



IONS



Appendix 29—1883.

APPENDIX 30.

COMPARISON OF RODMAN, WOODBRIDGE, AND CRUSHER GAUGES.

(1 plate.)

JUNE 1, 1882.

The ORDNANCE BOARD, U. S. A.,
New York Arsenal:

GENTLEMEN: I desire that the Board take up the matter of pressure gauges, and determine either in the course of its current firings, or if necessary by experimental firings expressly made for the purpose, the relative merits as regards the accuracy and uniformity of its indications, of the Rodman, the Woodbridge, and the English Crusher gauges.

The commanding officer of Frankford Arsenal has been furnished with drawings of the Rodman and Woodbridge gauges, but it will be necessary for the Board to prepare a design of the Crusher gauge.

This matter is a most important one, and it is desired that the Board will carefully investigate it, and submit a full report with its recommendations thereon.

Respectfully, your obedient servant,

S. V. BENÉT,
Brigadier General, Chief of Ordnance.

In accordance with the letter of the Chief of Ordnance dated June 1, 1882, trials were commenced for comparing the indicated pressures of the Rodman, Woodbridge, and Crusher gauges. These gauges are described and illustrated in the Report of the Chief of Ordnance for 1880, page 177 *et seq.* The Rodman and Woodbridge gauges have pistons terminating in heads provided with a pyramidal cutter in the first case, and in the second with a conical cavity, which, under the action of the powder gases, make indentations in the anterior faces of copper disks with which they are placed in contact before firing. The extent of the indentations is measured and the pressure is deduced from that required to produce the same effect in the testing-machine. The piston-head of the Crusher gauge terminates in a flat surface, which rests upon a small cylinder of copper, called the *Crusher*, which is compressed longitudinally by the action of the powder gases. The diminution of the length which the Crusher undergoes, compared with the pressure required to give the same diminution in the testing-machine, is taken as a measure of the pressure in the bore of the gun. The casings of the gauges were unequal in length, and, to avoid variations in pressure that might exist at different sections of the gaseous column, an arrangement had to be devised which would place the exterior ends of the pistons in the same plane perpendicular to the axis of the bore. For this purpose a wooden block was turned to fit accurately the base of the bore, which is cup-shaped and has the form of a conic frustrum, with a rounded corner at the small or posterior face. The forward part of the block was a cylinder. Holes were drilled in the face of the cylindrical part of the block, with such a diameter as to fit the casings of the gauges, and with such a depth that the faces of the pistons were in the same plane.

THE EXPERIMENTS.

The gauges secured in the block were placed in a cartridge-bag containing 35 pounds of powder and rammed home. A shot of 180 pounds weight was then placed in contact with the charge and the gun fired. The indications were unsatisfactory in the first and two subsequent rounds, due to the crushing of the wooden block. The Woodbridge gauge, which had been used before and repaired, was injured by the inflamed gases by reason of the inaccurate fitting of the piston. A steel block similar to the wooden one previously described was substituted in the subsequent rounds and gave satisfactory results. The steel block was first used on October 14, 1882. The Woodbridge gauge having been injured its indications in this series of rounds need not be considered.

The first three rounds, Nos. 336, 337, and 338, with the steel block were not satisfactory.

Five rounds were fired and are arranged below in the order of the velocities. The Crusher and Rodman disk were in each case subjected to a pressure of 18,000 pounds in the testing machine before firing.

TABLE I.

No.	Number of round in firing record.	Velocity at 109 feet.	Pressure in pounds per square inch.	
			Crusher.	Rodman.
		Feet.		
1	339	1, 298	25, 875	27, 500
2	342	1, 308	27, 750	31, 500
3	340	1, 330	28, 500	32, 500
4	341	1, 346	30, 250	35, 000
5	343	1, 367	31, 625	34, 000

In the following rounds the Crusher only was compressed under 18,000 pounds before firing:

TABLE II.

No.	Number of round in firing record.	Velocity at 109 feet.	Pressure in pounds per square inch.	
			Crusher.	Rodman.
		Feet.		
1	345	1, 278	25, 500	25, 500
2	346	1, 299	26, 750	27, 500
3	344	1, 338	27, 375	27, 500

In the next series neither of the gauges was compressed before firing.

TABLE III.

No.	Number of round in firing record.	Velocity at 109 feet.	Pressure in pounds per square inch.	
			Crusher.	Rodman.
		Feet.		
1	348	1, 315	27, 125	28, 000
2	347	1, 345	30, 125	33, 000

It will be seen that the pressures deduced from the Crusher are less than those indicated by the Rodman.

Table I shows the comparative pressures when both gauges receive initial compression, but the Rodman gauge is generally used without it. In all the above tables the Crusher is most sensitive to changes in velocity, and its simple construction makes it superior to the Rodman.

A new Woodbridge gauge with perfect accuracy in the fitting of the parts was procured from the Springfield Armory, and a second series of experiments in which comparative results were obtained from all three instruments was carried on at Sandy Hook March 7, 1883.

The results tabulated as before in the order of their velocities are given herewith. The same weights of charge and projectile were used as in the first series. Table IV shows the results when the Crusher alone was compressed under 18,000 pounds in the testing-machine:

TABLE IV.

No.	Number of round in firing record.	Velocity at 95 feet.	Pressure in pounds per square inch.		
			Crusher.	Woodbridge.	Rodman.
		Feet.			
1	391	1,264	18,000	20,800	22,000
2	392	1,270	20,250	22,000	19,500
3	389	1,273	19,000	21,600	18,500
4	390	1,279	20,250	22,000	21,000
5	393	1,315	23,500	24,000	22,000
6	394	1,320	25,000	24,400	22,000

In No. 3 of the above series all the gauges showed a lower pressure with a velocity of 1,273 feet than in No. 2, where the velocity was 1,270. In Nos. 1, 5, and 6 of the above series, where the velocities were 1,264, 1,315, and 1,320, the Rodman gave the same pressures, viz, 22,000 pounds. The other two gauges showed a pressure increasing with the velocity generally.

A final series was undertaken, in which all the gauges were placed in the testing-machine under a pressure of 18,000 pounds before firing.

TABLE V.

No.	Number of round in firing record.	Velocity at 95 feet.	Pressure in pounds per square inch.		
			Crusher.	Woodbridge.	Rodman.
		Feet.			
1	395	1,297	22,250	23,200	23,500
2	397	1,321	25,400	24,400	25,500
3	396	1,333	27,125	26,000	28,500

SUMMARY.

All the gauges give higher pressures when they are not given preliminary compression.

The pressures generally increase with the velocities.

The pressures with the Crusher and Woodbridge gauges increase more regularly than do those of the Rodman gauge.

The pressures indicated by the Crusher and Woodbridge gauges are generally less than those with the Rodman.

As far as the results are concerned there is no very great difference in any case, but the Crusher and Woodbridge are more sensitive to slight differences in velocity than the Rodman.

CONCLUSION.

The Board is of the opinion that the housing of the Crusher can be made so as to occupy less space than that for either the Woodbridge or Rodman; that the Crusher gauge is easier to manipulate, cheaper and simpler in its elements, than the other two. It is more easily duplicated, and as its results are quite as accurate, the Board recommends its use hereafter in obtaining pressures in the bores of guns.

Record of firing with 8-inch muzzle-loading rifle, No. 7, breech inser

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation in degrees.	Instrumental velocity taken 109 feet from gun.	Recoil.
		1882.		*Lbs.*	*	*Lbs.*		*Feet.*	*Feet.*
Barometer, 30.314; thermometer, 59; relative humidity, 42; wind, 11 miles an hour.	333	Oct. 4	Du Pont's Hexagonal E. V. J. No. 4. Density, 1.750. Granulation, 72.	35	Butler resaboted.	180	-¼	1,328	2.08
	334	Oct. 4		35		180	-¼	1,364	2.25
Barometer, 30.283; thermometer, 66; relative humidity, 40; wind, 6 miles an hour.	335	Oct. 4		35		180	-¼	1,293	2.75
Barometer, 29.994; thermometer, 60; relative humidity, 81; wind, 15 miles an hour.	336	Oct. 14		35		180	-¼	1,373	2.8
Barometer, 29.964; thermometer, 66; relative humidity, 63; wind, 24 miles an hour.	337	Oct. 14		35		181	-¼	1,342	3.00
	338	Oct. 14		35		181	-¼	1,329	3.00
Barometer, 29.958; thermometer, 66: relative humidity, 93; wind, 2 miles an hour.	339	Oct. 18		35		183	-¼	1,298	3.08
	340	Oct. 18		35		183	-¼	1,330	3.25
Barometer, 29.903; thermometer, 68; relative humidity, 90; wind, 6 miles an hour.	341	Oct. 19		35		182	-¼	1,346	3.50
	342	Oct. 19		35		183	-¼	1,308	3.25
	343	Oct. 19		35		184	-¼	1,367	3.08
Barometer, 30.183; thermometer, 51; relative humidity, 66; wind, 16 miles an hour.	344	Oct. 20		35		183	-¼	1,338	3.17
	345	Oct. 20		35		183	-¼	1,278	2.34
	346	Oct. 20		35		183	-¼	1,299	3.08
	347	Oct. 20		35		183	-¼	1,345	3.00
Barometer, 30.162; thermometer, 54; relative humidity, 74; wind, 10 miles an hour.	348	Oct. 20		35		183	-¼	1,315	3.00
								Taken 95 feet from gun.	
		1883.							
Barometer, 29.949; thermometer, 31; relative humidity, 78; wind, 35 miles an hour.	389	Mar. 7	Du Pont's Hexagonal E. V. M. Density, 1.750. Granulation, 72.	35	Butler new.	180	-¼	1,273	2.67
	390	Mar. 7		35		180	-¼	1,279	2.67
	391	Mar. 7		35		180	-¼	1,264	2.83
A. M.: Barometer, 30.054; thermometer, 28; relative humidity, 68; wind, 42 miles an hour.	392†	Mar. 7		35		180	-¼	1,270	2.67
	393	Mar. 7		35		180	-¼	1,315	2.58
	394	Mar. 7		35		180	-¼	1,320	2.67
	395	Mar. 7		35		180	-¼	1,297	2.75
P. M.: Barometer, 30.084; thermometer, 27; relative humidity, 64; wind, 44 miles an hour.	396	Mar. 7		35		180	-¼	1,233	2.75
	397	Mar. 7		35		180	-¼	1,321	2.67

* Imperfect indentation.

tion, at Sandy Hook, N. J., from October 4, 1882, to March 7, 1883.

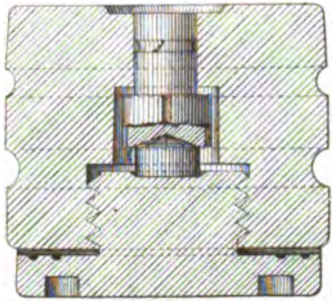
Direction of wind.	Pressure, pounds per square inch of bore.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	Crusher gauge.	Rodman knife.	Woodbridge gauge.		
From rear and slightly left.	26,750	26,500	28,000	Fired into sand butt to try pressure gauges.	In the three rounds (333, 334, and 335) wooden blocks were used, shaped to fit the cup at the bottom of chamber, in which were secured the pressure gauges (Rodman, Woodbridge, and Crusher), the block being placed at the bottom of the cartridge-bag, so that the Rodman gauge should be on the upper right-hand side, Woodbridge on the upper left, and Crusher at the bottom; 333 and 335 pine block; 334 oak block was used, block being nearly destroyed in each round. Rounds 333 and 335 (Woodbridge gauge) gas escaped through base-screw and around piston, scoring it, blackening disk and interior of gauge. In the three rounds (336, 337, and 338) steel block was used, shaped to fit the cup at the bottom of the chamber, in which were secured three pressure gauges (Rodman, Woodbridge, and Crusher), the block being placed at the bottom of the cartridge-bag, so that the Rodman gauge should be on top, the Woodbridge on the lower right-hand side, and the Crusher on the lower left-hand side. Round 336. In opening the Rodman gauge after firing, it was discovered that the knife had not been placed in the original cut. Round 337. The Crusher disk used in this round found upset after firing. In rounds 339 to 348, inclusive, steel block was used, shaped to fit the cup at the bottom of the chamber, in which were secured three pressure gauges (Rodman, Woodbridge, and Crusher), the block being placed at the bottom of the cartridge-bag, so that the Rodman gauge would be on top, the Woodbridge on the lower right-hand side, and the Crusher on the lower left-hand side. In rounds 339 to 343, inclusive, the disk of each gauge had a pressure applied of 18,000 pounds to the square inch before firing on Rodman testing machine. In rounds 344, 345, and 346, pressure applied (18,000 pounds per square inch) to Crusher disk only. In rounds 347 and 348, no pressure applied to any of the disks before firing.
	32,250	42,500	28,400		
From front and left.	26,500	27,000	24,400		
From rear and slightly right.	29,500	33,000	28,500		
From rear	31,750	30,000	27,200		
	29,500	31,500	28,800		
From left and slightly front.	25,875	27,500	(*)		
	28,500	32,500	25,200		
From rear and right.	30,250	35,000	28,000		
	27,750	31,500	(*)		
	31,625	34,000	30,000		
From rear	27,375	27,500	26,000		
	25,500	25,500	24,800		
	26,750	27,500	(*)		
	30,125	33,000	28,800		
	27,125	28,000	26,000		
From rear and right.	19,000	18,500	21,600		In rounds 389 to 397, steel block was used, shaped to fit the cup at the bottom of the chamber, in which were secured three pressure gauges (Rodman, Woodbridge, and Crusher), the block being placed at the bottom of the cartridge-bag, so that the Rodman gauge should be on top, the Woodbridge on the lower right-hand side, and the Crusher on the lower left-hand side. Area of piston of Rodman and Crusher, 0.1 square inch; area of piston of Woodbridge, 0.25 square inch. In rounds 389 to 394, inclusive, the disk of the Crusher gauge had a pressure applied of 18,000 pounds per square inch before firing on the Rodman testing machine; the Woodbridge and Rodman having no pressure applied previous to firing the above rounds. In rounds 395 to 397, inclusive, the disks of the Woodbridge, Crusher, and Rodman gauges had a pressure applied of 18,000 pounds per square inch before firing on Rodman testing machine. Bolt holding false trunnion for elevating rack on right side of carriage broke. Repaired by new one.
	20,250	21,000	22,000		
	18,000	22,000	20,800		
	20,250	19,500	22,000		
	23,500	22,000	24,000		
	25,000	22,000	24,400		
From right	22,250	23,500	28,200		
	27,125	26,000	28,500		
	25,400	24,400	25,500		

† Steel block containing pressure plugs thrown out of gun.

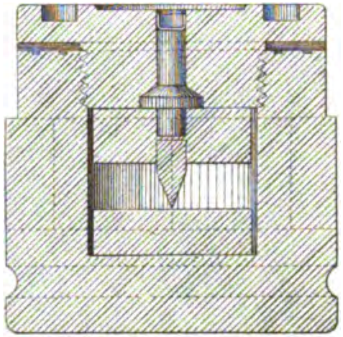
PLATE I.

INTERNAL PRESSURE GAUGES

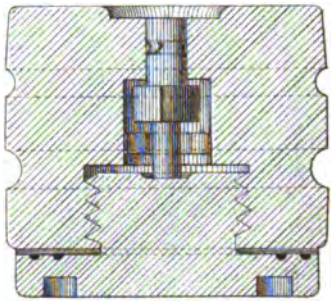
WOODBRIDGE



RODMAN



CRUSHER



U. S. ORDNANCE BOARD
Governors Island April 2d 1883.

SCALE OF 10 8 6 4 2 0 1 2 3 INCHES.

In compliance with the instructions conveyed in a letter from the Chief of Ordnance, U. S. A., of September 21, 1882, the Board has the honor to submit herewith a design for a steel field gun, accompanied with a statement exhibiting the theoretical and practical considerations upon which the design has been prepared.

In foreign armies batteries for the field service are divided into three classes, viz: horse, light field, and heavy field. The design herewith presented is according to instructions for a piece intermediate between the lightest and heaviest guns.

The appended table gives a list of the horse and light field artillery pieces of the principal foreign armies. The classification is not entirely reliable, as the sources whence the information was derived did not always specify to what class the guns belonged.

From a consideration of the table the following data were adopted as bases for calculation:

Caliber of piece	inches	3.2
Weight not to exceed	pounds	750
Preponderance	do	50
Length of bore	calibers	26
Powder charge	pounds	3.25
Projectile:		
Length	calibers	2.8
Weight	pounds	13

As much relating to the gun must be tentative in its nature, a factor of safety of four was adopted.

No accurate results exist for determining the pressure due to different densities of I. K. powder, the kind to be used in our field guns. It was deemed best therefore to take those carefully tabulated in the report of Messrs. Abel and Noble in their researches upon fired gunpowder of the R. L. G. type used in the British service. This has a less specific gravity than the I. K. powders, and will undoubtedly give higher pressures from the same density. Any errors resulting from the use of tables giving densities and pressures for the R. L. G. powder will be errors in defect and on the side of safety.

One feature of the design submitted is causing the seat for the interrupted screw to be cut in a ring which is screwed into the jacket. The tube is thus free from longitudinal strain, except such as ensues from the gaseous pressure on the base of the projectile.

Calculations for shrinkage have not been made, as further information on the subject must be obtained from test specimens and the experience of the manufacturer. The calculations for strength and elastic limit were based upon reports obtained from steel-makers and may have to be modified hereafter.

There is but little doubt that the gun as designed will prove a safe and powerful weapon, comparing favorably with those now existent, and it is more than probable that it will exceed its calculated power.

In order to ascertain the facilities of the steel manufacturers of this country to produce steel of the necessary physical qualities, the Board addressed a circular letter to quite a number of manufacturers, asking for information as to the extent and nature of their productions, to which a reply was generally received. It would appear from these statements that there are several manufacturers who possess the necessary facilities for producing the quality of steel needed, but the Midvale Works seemed to be better prepared to produce this steel in a short time.

To procure some practical information with regard to the methods pursued in producing steel by the open-hearth and Bessemer processes, the Board requested and obtained authority to visit the Midvale and Albany and Rensselaer Steel Works, which represent the two modes of manufacture. The Midvale Works were found to possess all the necessary plant for producing suitable steel for guns of this caliber, and from the extreme care exercised in the various operations of the manufacture, as well as the careful chemical analysis of the metal in its different stages, it would appear that they could easily duplicate any required product.

The Albany and Rensselaer Works produce enormous quantities of Bessemer steel, but as the purposes for which this steel is generally employed do not demand the physical characteristics needed for gun constructions, no careful or detailed analysis is made of their productions, and the Board does think that they are at present in a condition to undertake the manufacture of a suitable steel for our purposes.

The Board would therefore recommend that the following test specimens be ordered from the Midvale Works and tested, viz:

BODY OF GUN.

1. A steel tube 24 inches in length, 7 inches exterior diameter, 2 inches interior diameter, and having a tensile strength of 85,000 pounds per square inch, an elastic limit of 36,000 pounds, and an extension to be determined.

JACKET.

2. A steel tube 15 inches in length, 10 inches exterior diameter, 5 inches interior diameter, and having a tensile strength of 95,000 pounds per square inch, an elastic limit of 42,000 pounds, and an extension to be determined. This specimen to be tempered in oil.

From the first specimen test pieces will be taken and tested for physical qualities, and the remainder will be finished to the calculated dimensions of the breech of the gun. From the second specimen three rings will be cut 4 inches in length, one of them being straightened for tests, and the other two to be shrunk onto the first piece, with shrinkage to be determined by calculation. In case the results are unsatisfactory the remaining ring will be finished with different dimensions.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Nature.	Nation or manufacture.	Denomination.	Material.	Caliber, inches.	Weight, pounds.	Preponderance, pounds.	Length.		
							Total, inches.	Bore.	
								Inches.	Caliber.
Horse	Krupp	7.5^{cm}	Steel hooped	2.95	517	....	70.87	......	......
	Austrian	8^{cm} (7.5^{cm})	Compressed bronze	2.95	660	....	......	......	......
	English	9-pdr. M. L	Steel body, wrought-iron jacket.	3	672	....	71	66	22
	Spanish	8^{cm}	Steel body, transformed Krupp.	3.09	737	....	76.18	68.07	22
	German	8-pdr., mod. '73	Steel hooped	3.09	858	100	82.67	74.21	24
	German	....	....	3.15	....	....	......	......	......
	French	8^{cm}	Steel hooped	3.15	935	36	89.76	83.54	26.5
	Russian	....	Steel hooped, Krupp, mod. '77.	3.45	793	99–117	66.93	57.68	16.8
	Russian	....	Steel hooped, Russian, mod. '79.	3.43	802		66.93	57.68	16.8
	American	M. L	Wrought iron	3	820	....	......	64.5	21.5
Light field	English	13-pdr	Steel, wrought-iron jacket	3	952	....	89	84	26
	Armstrong (Spanish).	8^{cm} (7.6^{cm})	Steel, wrought-iron jacket, M. L. & B. L.	3	925	....	85	81.49	27
	Spanish	8^{cm}	Steel jacketed, Sotomayer	3.15	532.4	....	87.08	80.71	25.6
	French	8^{cm}	Steel hooped	3.15	935	36	89.76	83.54	26.5
	Swiss	8.4^{cm}	Steel hooped, Krupp	3.307	935	103	84.65	76.06	23
	Italian	9^{cm} (8.7^{cm})	Steel hooped, Krupp	3.425	1,082	....	88.46	74	21.5
	Russian	....	Steel hooped, Krupp, mod. '77.	3.43	973	119–139	82.68	73.43	21.4
	Russian	....	Steel hooped, Russian, '79.	3.43	1,005		82.68	73.43	21.4
	Austrian	....	Compressed bronze wedge fermeture.	3.43	1,071	....	81.10	72.05	21
	Austrian	9^{cm} (8.7^{cm})	....	3.15	....	....	......	......	......
	German	9^{cm}, mod. '73	Steel hooped	3.46	990	100	82.67	73.43	21
	American	3″ converted	Steel breech	3.2	826	....	72.65	64.85	20.2
	....	....	Projected steel gun	3.2	722	....	89.2	83.2	26

Twist.		Grooved.			Powder chamber.		Powder charge.		Projectile.		Initial velocity, feet.	Pressure per sq. inch, lbs.	Muzzle energy.			
Feet.	Caliber.	Width, inches.	Depth, inches.	Number.	Length, inches.	Diameter, inches.	Weight, pounds.	Nature.	Length caliber.	Weight, pounds.			Total, foot-tons.	Sq. inch shots, cross section, foot-tons.	Per pound of powder, foot-tons.	Per pound of weight of gun, ft.-lbs.
.....	32	0. 2756	0. 049	24	6. 77	3. 19	1. 65	Large grains..	.....	9. 5	1, 378	12, 270	125	18. 3	76. 09	543
.....	45	0. 275	0. 049	24	.....	.....	2. 09	Aust. field	.....	9. 9	1, 378	......	130. 3	19	62. 4	443
.....	30	0. 8	0. 11	3	.....	.....	1. 75	R. L. G........	.....	9	1, 381	......	118. 9	17	68. 2	397
.....	49	0. 70	0. 05	12	10. 52	3. 48	2. 31	Gr. 39 to 59, Span. powd'r.	2. 5	10. 12	1, 492	......	156. 1	21	68	475
.....	50	......	0. 049	24	13. 97	....	2. 75	....	2. 5	11, 15	1, 522	......	179. 0	24	65	467
1° 7'	to 30°	0. 31	......	24	16. 33	3. 27	3. 3	Gr. 24, D. 1. 745	2. 8	12. 3	1, 607	......	220. 2	28	67	520
... .	8 to 36	0. 33	0. 049	24	11. 43	3. 86	2. 99	....	2. 36§	15. 12	1, 350	......	191. 0	20. 4	63	540
.....	8 to 36	0. 33	0. 049	24	11. 43	3. 86	2. 99	....	2. 36	15. 12	1, 350	......	191. 0	20. 6	63	533
.....	30	0. 5	0. 05	13	11. 5	3. 5	3. 125	R. L. G	3. 16§	13	1, 595	......	230 8	32. 4	78. 6	543
*	......	0. 498	0. 047	..	12. 27	3. 7	3. 5	....	.....	13	1, 600	28, 000	230. 7	32. 4	65. 6	558
†	......	......	0. 0197	16	13. 32	3. 54	3. 41	Cubic (density 1.76) 11mm.	3	13. 86	1, 492	......	214	27. 4	62. 7	900
1° 7'	to 30°	0. 31	......	24	16. 33	3. 27	3. 3	Gr. 24, D. 1. 745	2. 8	12. 3	1, 607	......	220. 2	28. 2	66. 7	527
‡	......	0. 314	0. 049	24	.....	....	3. 08	D.1.64, G. 29x39	.....	13. 71	1, 502	......	214. 4	24	69. 6	513
.....	46	0. 30	0. 043	24	.....	....	3. 19	D. 1.67, Gr. .276 to .430.	.....	15. 14	1, 490	30, 000	233. 0	25. 3	73	482
.....	8 to 40	0. 33	0. 049	24	10. 75	3. 86	2. 99	....	2. 36§	15. 12	1, 450	......	220. 3	23. 9	73. 6	507
....	8 to 40	0. 33	0. 049	24	10. 75	3. 86	2. 99	....	2. 36	15. 12	1, 450	......	220. 3	23. 9	73. 6	491
.....	46	0. 318	0. 049	24	13. 78	....	3. 3	Aust. field	2. 5	13. 97	1, 476	......	210. 9	22. 8	63. 9	442
.....	50	.....	0. 049	24	14. 57	....	3. 6	....	2. 5	15. 4	1, 460	......	227. 6	24	63. 2	515
.....	.....	.....	.....	..	.....	....	.....	....	.....	.....	.....	......	210. 11	26. 10	70. 11	569
.....	30	0. 332	0. 05	24	10	3. 8	3. 25	I. K., gr. 2,200, D. 1.725.	2. 8§	13	1, 561	......	220	27. 3	67. 7	682

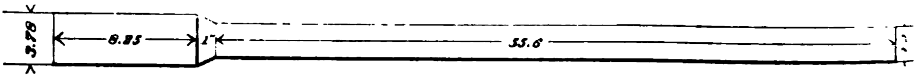
* Increasing to 3 calibers, then uniform.
† Increasing 1 turn in 50 to 1 in 22.
‡ Increasing final 1 in 42.
§ Shell.

PROJECTED STEEL 3.2 inch B. L. R.

1. *Experimental data obtained from the firing of* 3.2 *inch Converted Rifle No.* 774, *at Sandy Hook.*

Velocity at 90 feet, 1,527 feet (mean of 12 results).
Maximum pressure, 35,000 pounds.
Charge, 3 pounds.
Weight of projectile, 12 pounds.

SKETCH OF BORE.



Formula for vol. of cone in front of chamber.

$$\frac{h}{3}\left(A+B+\sqrt{AB}\right.$$

VOL. CHAMBER.

Log π=0.49715
$d^2=\overline{3.78}^2$=1.15498
a. c. 4=9.39793
1.05006=11.221=area sect. A.
Length, 8.25 inch=0.91645
Log. vol. cham.=1.96652 . . . . vol. cham., 92.58

VOL. BORE.

π=0.49715
$d^2=\overline{3.2}^2$=1.01030
a. c. 4=9.39793
0.90538= 8.042=area sect. B.
Length, 55.6=1.74507
Log. vol. rifled part of bore. 2.65046 . . . . vol. rifled part bore 447.15
2)1.95545
0.97772 = 9.500= $\sqrt{AB}$

3)28.763
9.587

Vol. of cone in front of chamber= 9.59

Total volume of bore=549.32

Instrumental velocity at 90 feet being 1,527 feet, what is the muzzle velocity?

Bashforth's formula is

$$S_V=S_v-\frac{d^2\,S}{W}$$

in which—

S_V=Tabular number corresponding to muzzle velocity.
S_v =Tabular number corresponding to instrumental velocity.
d =Diameter of projectile.
W=Weight of projectile.
S =Distance from muzzle to point at which instrumental velocity is determined.

Substituting numerical values, the formula becomes

$$S_v = S_{1527} - \frac{\overline{3.2^2}}{12} \times 90$$

$S_{1527} = 754.83$

$\text{Log } \overline{3.2^2} = 1.01030$
$90 = 1.95424$
$\text{a. c. } 12 = 8.92082$

$1.88536 \qquad = 76.80$

$S_v = 678.03$
$S_v \text{ for } 1544 = 676.80$

$D = 1.23$

$S_v \text{ for } 1543 = 681.2$
$S_v \text{ for } 1544 = 676.8$

$D = 4.4$

4.4)1.23(0.27

$S_v \text{ for } 1543.73 = 678.03$

Hence the muzzle velocity = 1543.73

The charge being 3 pounds, the muzzle velocity being 1543.73 feet, and the projectile weighing 12 pounds, what is the work at the muzzle per pound of powder in foot tons?

$$\text{Work } Q = \frac{12}{2 \times 32.16 \times 2240 \times 3} \overline{1543.73^2} = \frac{\overline{1543.73^2}}{36019}$$

$\text{Log } \overline{1543.73^2} = 6.37713$
$36019 = 4.55653$

$1.82059 = 66.1568$

Actual work resulting from experiment $Q = 66.1568$

Calculated work from preceding data.

Volume occupied by charge = 27.73 × 3 = 83.19
Volume of bore = 549.32

Log . . . . 549.32 = 2.73982
Log . . . . 83.19 = 1.92007

Log of expansion to fill bore = 0.81975

Therefore number of expansions = 6.6.

Log chamber . . . . 92.58 = 1.96652
Log charge . . . . = 1.92007

Log expansion required to fill chamber = 0.04645

Number of expansions = 1.11.

Work in foot tons corresponding to 6.6 = 102.333
Work in foot tons corresponding to 1.11 = 9.637

Calculated effective work . . . . . . = 92.696

The above data for calculated work were taken from Table XI of Noble and Abel's experiments—last edition.

Comparison of actual and calculated work per pound of powder.

Actual work =66.1568 log 1.82059
Calculated work=92.696 1.96706

$\bar{1}.85353$=0.71372

Hence percentage to be used in calculating with Table XI is 0.7137.

Calculation of distance over which the projectile moves when maximum pressure exists.

Maximum pressure=35.250 pounds.
2240)35.250(15.29 tons.

For R. L. G. powder, 15.29 tons corresponding to 0.662 density:
Volume of charge=27.73×3=83.19
0.662)83.19(125.66=volume in which required density is reached.
92.58=volume of chamber.
33.08=volume of rifled part of bore.
Area of section bore=8.042)33.08(4.10 inches length of bore in front of chamber.

Summary.

Factor to be used with Table XI of new edition of Noble & Abel equals 0.7137.

Distance in front of chamber where maximum density is reached equals, say, 4 inches.

Assumed data.

Weight of charge=3.25 pounds.
Density of loading=32.07 c. i. per pound.
Length of chamber=10 inches.
Maximum diameter=3.8 inches.
Volume of elliptical cham=104.24 c. i.
Total length of bore=26 calibers.
Diameter of bore=3.2 inches.
Length of bore in inches=3.2×26=83.2 inches.
Length of rifled part of bore=83.2−10=73.2 inches.

I.—*Volumes.*

Rifled part of bore:

$$\frac{\pi d^2}{4}\times l$$

d=diameter= 3.2
l=length =73.2

Area of section of bore:
Log π=3.1416=0.49715
$D^2=\overline{3.2}^2$ =1.01030
a. c. log 4=9.39794 0.90539=8.0425=area section of bore.
Log l=73.2 =1.86451

2.76990= 588.71=volume rifled part of bore.
104.24=volume chamber.

692.95

II.—*Maximum pressure when shot has moved 4 inches.* (*See Summary, above.*)

For the calculation of pressures Table XVIII, page 129 of Noble and Abel's first treatise and that portion of it relating to R. L. G. powder is used. This powder has a density of 1.68, and will therefore give higher pressures than the I. K. B. powder density 1.725, which will be used in this gun, but it is considered best to use a higher pressure to provide for contingencies.

Charge 3.25 pounds log=0.51188
Density unity 27.73 1.44275

1.95463

Therefore, volume occupied by charge at density 1=90.08.

Log section of bore . . . . . . =0.90539
Log space passed over by projectile when maximum pressure ensues (4 inches) . . . . =0.60206

1.50745= 32.170
Volume chamber . . . . =104.24

Volume occupied by gas when the pressure is a maximum . . . . 136.41 log=2.13485

Log volume occupied by gas at density 1 =1.95463
Log volume occupied by gas at maximum pressure=2.13485

Log density of gas when pressure is maximum=$\bar{1}.81978$

Therefore, density=.66.

From Table XVIII, density .66=pressure of 15.45 tons.

Log 15.45=1.18893
Log 22.40=3.35025

Log pressure in pounds=4.53918

Therefore, pressure=34,608 pounds.

Pressure at different points of the bore in front of chamber.

The points selected are at the following distances from the face of the chamber:

1st. 4'' determined above
} 4''.2
2d. 8''.2
} 5''
3d. 13''.2
} 10''
4th. 23''.2
} 10''
5th. 33''.2
} 10''
6th. 43''.2
} 10''
7th. 53''.2
} 10''
8th. 63''.2
} 10''
9th. 73''.2

Volume of chamber and bore up to point of maximum pressure=136.41.

Volume bore for 4″.2:
Log section bore=0.90539
Log 4″.2=0.62325
1.52864=33.78

Volume bore for 5″:
Log section bore=0.90539
Log . . . 5″=0.69897
1.60436=40.21

Volume bore for 10″:
Log . . . 2=0.30103
1.90539=80.42

	Logarithms.	Density.	Pressure in tons per square inch.	Distance from face of chamber.
Log charge density 1	1.95463			
Second section: 136.41 33.78				
170.19	2.23093			
	1̄.72370	0.529	10.89	8″.2
Third section: 40.21	1.95463			
210.40	2.32305		D=0.24 3	
	1̄.63158	0.43	0.72 40=7.65 8.37	13″.2
Fourth section: 80.42	1.95463			
290.82	2.46362			
	1̄.49101	0.31	D=0.24 30=5.39 5.63	23″.2
Fifth section: 80.42	1.95463			
371.24	2.56965		D=0.20 4	
	1̄.38498	0.24	0.8 20=3.33 4.13	33″.2
Sixth section: 80.42	1.95463			
451.66	2.65481			
	1̄.29982	0.2	3.33	
Seventh section: 80.42	1.95463			
532.08	2.72598		D=.196 2	
	1̄.22865	0.17	.392 .15=2.35 2.74	
Eighth section: 80.42	1.95463			
612.50	2.78711			
	1̄.16752	0.15	2.35	
Ninth section: 80.40	1.95463			
692.9	2.84067		D=.166 3	
	1̄.11396	0.13	.498 .10=1.37 1.87	

Work and corresponding velocities determined at nine different points of the bore, the same points being taken as those used above.

The factor of effect deduced from the firing of the 3".2 converted rifle, No. 774, and applied with Table XI, of Noble and Abel's new treatise (page 236 *et seq.*), is 0.7137. (See Summary.)

The work done depends upon the number of expansions. To determine the expansions find the volume of the bore (including the chamber) up to the point at which the number of expansions is desired and divide this volume by 90.08; that occupied by the powder charge of 3.25 pounds at the density unity. Entering the table with the quotient as an argument, the corresponding work in foot-tons may be obtained. Subtract from this the work due to the expansion of the charge required to fill the chamber and multiply the result by the factor of effect 0.7137 and product will be the work done up to the required point. From this the corresponding velocity may be deduced.

Work to be deducted for expansion required to fill chamber.

$$\begin{array}{lr} \text{Log volume of chamber (104.24)} = & 2.01803 \\ \text{Log volume charge at density 1. (90.08)} & 1.95463\ \ldots\ a.c. = 8.04537 \\ \hline & 0.06340 = 1.16 \end{array}$$

For expansion of 1.16 (Q) work to be deducted=13.33. (See Table XI.)

Work Q at different points of bore and corresponding velocity.

$$\text{Formula } V=\sqrt{\underbrace{\frac{2\times\overset{[g]}{32.16}\times\overset{[\text{lbs. in ton}]}{2240}\times\overset{[\text{charge}]}{3.21}\times\overset{[\text{factor}]}{7137}}{\underset{\text{Wt. projectile}}{13}}}_{A.}}\cdot\sqrt{Q}.$$

$$\text{Log } A\left\{\begin{array}{r} \text{Log } 2=0.30103 \\ 32.16=1.50732 \\ 2240=3.35025 \\ 3.25=0.51188 \\ 0.7137=\bar{1}.85352 \\ a.c.\ 13=8.88606 \\ \hline 2)4.41006 \end{array}\right.$$

$$\text{Log } \sqrt{A}=2.20503$$

Distance from face of chamber.	Corresponding volumes. See pages 294, 295, and 296.	Log. of volumes + a. c. log. of charge (8. 04537).	No. of expansions.	Work corresponding to (4); work lost=(13.33 foot tons) Q.	Log. $\sqrt{A}$=2.20503 + log. $\sqrt{Q}$.	Corresponding velocity.	Difference.
4″	6 41	2. 13485 8. 04537	E. 1. 51	32. 42 13. 33	2. 20503 0. 64041	700. 55	
		0. 18022		19. 09	2. 84544		
8. 2	170. 19	2. 23093 8. 04537	1. 89	45. 91 13. 33	2. 20503 0. 75648	915. 19	
		0. 27630		32. 58	2. 96151		
13. 2	210. 40	2. 32305 8. 04537	2. 34	57. 319 13. 33	2. 20503 0. 82167	1063. 4	179. 7
		0. 36842		43. 989	3. 02670		
23. 2	290. 82	2. 46362 8. 04537	3. 23	73. 42 13. 33	2. 20503 0. 88911	1242. 1	101. 6
		0. 50899		60. 09	3. 09414		
33. 2	371. 24	2. 56965 8. 04537	4. 12	83. 566 13. 33	2. 20503 0. 92328	1343. 7	
		0. 61502		70. 236	3. 12831		
43. 2	451. 66	2. 65481 8. 04537	5. 01	91. 385 13. 33	2. 20503 0. 94620	1416. 5	72. 8
		0. 70018		78. 055	3. 15123		
53. 2	532. 08	2. 72598 8. 04537	5. 91	97. 981 13. 33	2. 20503 0. 96382	1475	58. 5
		0. 77135		84. 651	3. 16885		
63. 2	612. 50	2. 78711 8. 04537	6. 8	103. 48 13. 33	2. 20503 0. 97748	1522. 3	47. 3
		0. 83248		90. 15	3. 18251		
73. 2	692. 9	2. 84067 8. 04537	7. 7	108. 177 13. 33	2. 20503 0. 98851	1561. 5	39. 2
		0. 88604		94. 847	3. 19354		

Thickness of gun at maximum diameter of chamber.

For calculating this thickness a factor of safety of 4 has been assumed. The gun is supposed to resist equally at every point of its cross-section.

Data used for calculating resistance.

	Ultimate tenacity.	Extension.	Elastic limit.	Extension.
Jacket, oil-tempered	95, 000 pounds or 42.41 tons.	....	42. 000	....
Body, soft	85, 000 pounds or 37.94 tons.	....	38. 000	....

Elastic limit taken at about 45 per cent.
Radius (maximum) of chamber=1.9.
Pressure (maximum) in chamber=15.45 tons. (See page 295.)
Thickness (minimum) of wall=1.1 (assumed).
Tenacity of metal in body=13.94 tons.

Log 15.45=1.18893	
Log 1.9=0.27875	
Log bursting strain=1.46768=	29.355
Log 37.94=1.57910	4
Log 1.1=0.04139	117.420
Log resistance of chamber=1.62049=	41.734
Unbalanced pressure=	75.686

Thickness required for jacket to overcome pressure of 75.734 tons.

Log 75.686=1.87902
Log ultimate tenacity of metal (42.41)=1.62747

0.25155=1″.78

Radius of surface of contact of body and jacket for maximum resistance—

$$S=\sqrt{rR}=\sqrt{1.9\times 4.78}=\sqrt{9.082}=3.013 \text{ inches, say 3 inches.}$$

Elastic resistance of chamber.

In the absence of accurate data the elastic resistance to compression has been assumed equal to that for extension. The resistance is calculated both by Claverino's and Vergile's formulæ.

Elastic resistance of jacket$=\theta_1=42.000$
Elastic resistance of body$=\theta_0=36.000$

Interior radius of body:

$R_0=1.9$ $R_0^2=3.61$

Interior radius of jacket:

$R_1=3$ $R_1^2=9$

Exterior radius of jacket:

$R_2=4.78$ $R_2^2=22.85$

P_0=pressure on bore.
P_1=pressure on surface of contact of body and jacket.

CLAVERINO.

$$P_1=\frac{3\theta_1\,(R_2^2-R_1^2)}{4\,R_2^2+R_1^2}=\frac{3\times 42000\,(22.85-9)}{4\times 22.85+9}=\frac{126000\,(13.85)}{100.5}$$

$$P_0^1=\frac{3\theta_0\,(R_1^2-R_0^2)+5\,P_1R_1^2}{4R_1^2+R_0^2}=\frac{3\times 36000\,(9-3.61)+781380}{4\times 9+3.61}$$

$$\frac{108000\,(5.39)+781380}{39.61}$$

Log 126000=5.10037
13.85=1.14145
a. c. 100.5=7.99783

Log P_1=4.23965
Log $5\times R_1^2=45$=1.65321

Log $5\times P_1\times R_1^2$=5.89286
$\therefore$ $5\,P_1\times R_1^2$=781380.

$P_0^{(1)}$.

Log 108000=5.03342
5.39=0.73159

5.76501

582120
$5\,P_1R_1^2$= 781380

Log 1363500=6.13466
a. c. log 39.61 8.40220

Log $P_0^{(1)}$=4.53686 $\therefore$ $P_0^{(1)}$=34424

$P_0^{(2)}$. Formula:

$$P_0^{(2)}=\frac{3\rho^2\,(R_1^2-R_0^2)+3\,P_1R_1^2}{4\,R_1^2-R_0^2}=\frac{108000\times5.39+468820}{32.39}$$

Log P_1 =4.23965
$3\times R_1^2=27$=1.43136

5.67101

108000×5.39= 582120
468820

1050940=6.02156
a. c. log 32.39=8.48959

Log $P_0^{(2)}$=4.51115=32445

$\therefore P_0^{(1)}>P_0^{(2)}$

VIRGILE.

$$P_1=\frac{\theta_1\,(R_2^2-R_1^2)}{R_2^2+R_1^2}=\frac{42000\,(22.85-9)}{22.85+9}=\frac{42000\times13.85}{31.85}$$

Log 42000=4.62325
13.85=1.14145
a. c. 31.85=8.49689

4.26159
18.264

$$P_0=\frac{R_1^2-R_0^2}{R_1^2+R_0^2}(\theta_0+P_1)+P_1=\frac{9-3.61}{9+3.61}\left(\begin{array}{l}36000\\ \underline{18264}\end{array}+18264\right)+18264$$

$$=\frac{5.39}{12.61}\ (54264)+18264$$

$$\begin{array}{rl}\text{Log } 5.39 & =0.73159\\ 54264 & =4.73451\\ \text{a. c. } 12.61 & =\underline{8.89928}\\ & 4.36538=\underline{23194}\\ & P_0=41458\end{array}$$

$$\begin{array}{ll}P_0 \text{ by Claverino} & =32445\\ P_0 \text{ by Virgile} & =\underline{41458}\\ & 2)\underline{73903}\\ \text{Mean} & 36951\end{array}$$

Maximum P_0 by highest pressure obtained (see p. 295)=34608

This pressure calculated on the basis of R. L. G. powder is higher than ordinarily exists with I. K. B. powder used, and the above results are considered as satisfactory. In the subsequent calculations Claverino's formulæ will be used as $P_0=32445$ will, it is believed, seldom be exceeded in the course of ordinary firing.

Distance from face of chamber at which the jacket may terminate.

Where the jacket ends consider the gun as a simple tube and calculate its strength under the hypothesis that its resistance varies inversely as the radii.

The area "A" representing the total resistance may be obtained by quadrature of the equilateral hyperbola whose equation is $xy=m$, but, for convenience, and as in this particular case the error will be small, it is calculated as a trapezoid for which

$$A=\frac{S+\frac{Sr}{R}(R\text{-}r)}{2}$$

In which—

A=resistance per □″ of cross-section in tons

S=Tensile strength of metal=37.94 tons

R=Exterior radius= (say) 2.6

r=Interior radius=1.6

From examinations based on preceding data and the resulting graphic construction a radius of about 2″.6 is believed to be a suitable thickness for the piece where it begins as a simple tube, and the calculations made are not intended to find the point exactly, at which the jacket shall terminate but to ascertain if the graphic construction already made will insure safety. Therefore an exterior radius of 2″.6 is assumed, and the question is whether the assumption is permissible or not.

Substituting numerical values in the above formula we have

$$A=\frac{\left(37.94+37.94\frac{1.6}{2.6}\right)}{2}2.6-1.6$$

Log 37.94=1.57910
1.6=0.20412
AC 2.6=9.58503

$\text{Log } 37.94\left(\frac{1.6}{2.6}\right)=1.36825=23.34$
37.94

2)61.28

A=30.64

A=Resistance——divided by factor of safety (4)=7.66, hence the jacket may end at that point where the internal pressure of the gas does not exceed 7.66 tons. The radius of the bore being 1.6 the pressure per square inch to which it may be subjected in order that it may not exceed 7.66 tons will be—

$$\frac{7.66}{1.6}=4.78 \text{ tons per square inch.}$$

(1) What density will give the pressure 4.78 tons?
Table XVIII of Noble and Abel's first work, page 129, gives for R. L. G. powder the following:

Density, 0.30; pressure, 5.39 tons.
Density, 0.25; pressure, 4.34 tons.

5)1.05
Difference for pressure of .01= .21

Calculated pressure as above, 4.78
Tabular pressure, 4.34

Difference, .44

21 : 44::1 : 21

Whence density required to give calculated pressure in the bore is 0.271.

(2). At what point of the bore is the density equal to 0.271.

Log charge density 1=1.95483
Log 0.271=$\bar{1}$.43297

Volume in which required density is reached 2.52186=332.55
Volume chamber, 104.24

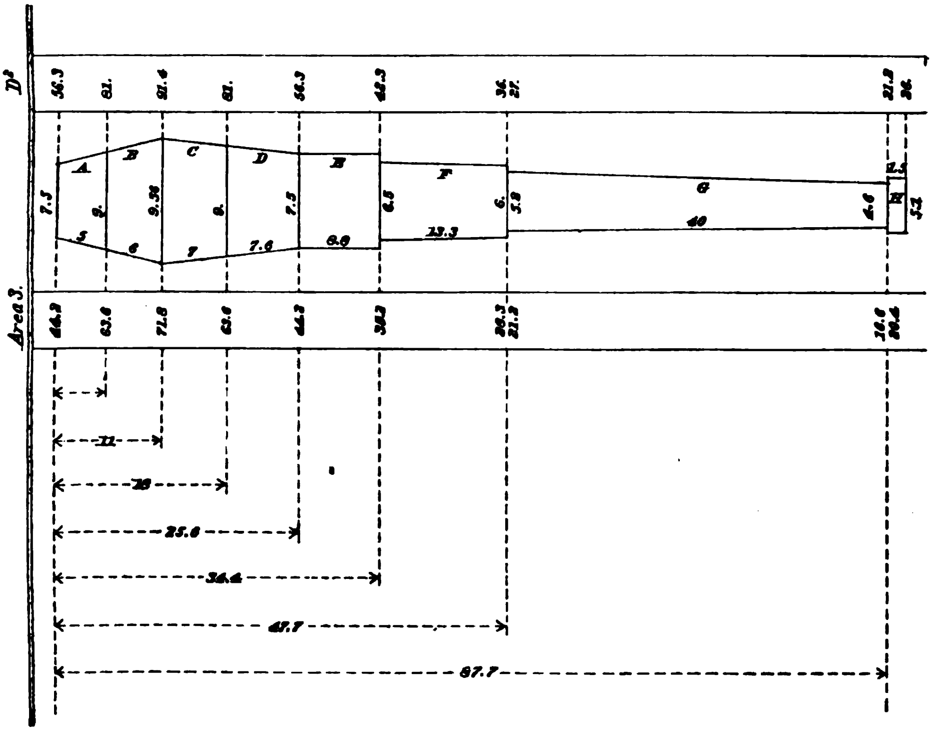
228.31=2.35852
Log section of bore=0.90538

1.45314
28″.4

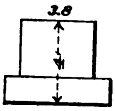
Distance from front of chamber to point at which jacket ends=28.4. As the resistance probably diminishes more rapidly than inversely as the radii, the jacket has been continued to a point 3″.3 beyond that determined in the calculation.

PROJECTED STEEL 3.2 INCH B. L. R.

VOLUMES, WEIGHTS, CENTERS OF GRAVITY.



TRUNNIONS.



Area, 11.3

$$\begin{array}{r} \text{Volume: } 11.3 \\ 4 \\ \hline 45.2 \\ 2 \\ \hline 90.4 \end{array}$$

Form of frustum of cone, volume=$\frac{1}{3}h(A+B+\sqrt{AB})$ a. c. log. 3=9.5229

(A)
A=44.2 log, 1.6454
B=63.6 1.8035

$\sqrt{AB}$ 2)3.4489

53 1.7244

160.8=2.2062
5=0.6990
a. c. 3=9.5229

2.4281= 268.

(B)
A=63.6=1.8035
B=71.8=1.8561

3.6596
$\sqrt{AB}$ 67.6 1.8298

203.=2.3075

6=0.7782
a. c. 3=9.5229

2.6086= 406.

(C) $A+B+\sqrt{AB}$=203.=2.3075
As in (B).
7=0.8451
a. c. 3=9.5229

2.6755= 474.

(D) $A+B+\sqrt{AB}$=160.8=2.2062
Same as (A).
7.6=0.8808
a. c. 3=9.5229

2.6099=407.4

(E) Cylinder.
44.2=1.6454
8.8=0.9445

2.5899= 389.

(F)
32.2=1.5224
28.3=1.4518

2.9742

30.7 1.4871

92.2=1.9647

13.3=1.1239
a. c. 3=9.5229

2.6115= 409.

(G)
21.2=1.3263
16.6=1.2201

2.5464

18.8 1.2732

56.6=1.7528
40. =1.6021
a. c. 3. =9.5229

2.8778= 755.

(H) Cylinder
204=1.3096
15=0.1761

1.4857= 30.6

3139.

Volume of piece as a solid=3139.
Volume chamber and bore= 692.95

Volume of piece =2446. log=3.38846
log weight c. i. steel $\bar{1}$.45344

2.84290

Weight used for calculating prepond.=696.47
Volume trunnions 90.4=1.95617
c. i. steel =$\bar{1}$.45344

1.40961 25.7

Total weight piece 722.17 pounds.

Center of gravity.

Formula for position of center of gravity from large end of frustum

$$l=\frac{h}{4}\left(\frac{3d^2+2\,\mathrm{D}d+\mathrm{D}^2}{d^2+\mathrm{D}a+\mathrm{D}^2}\right)$$

a. c. 4 = 9.3979

(A)

$$l=\frac{5}{4}\left(\frac{3\times 56.3+2\times 9\times 7.5+81}{56.3+\quad 9\times 7.5+81}\right.$$

3	9	67.4
		56.3
168.9	67.4	
134.8	2	204.7
81		
	134.8	

log 384.7 = 2.5852
2.3135

0.2727
5 = 0.6990
a. c. 4 = 9.3979
5
0.3696 = 2.34

l = 2.66 log = 0.4249
log Vol. A = 2.4281

moment = 2.8530 = 713.

(B)

$$l = \frac{6}{4}\left(\frac{3 \times 81 + 2 \times 9 \times 9.56 + 91.4}{81 + 9 \times 9.56 + 91.4}\right.$$

3 9 86.04
81
243 86.04
172.08 2 258.44
91.4
172.08
506.48 = 2.70456
2.41236

0.29220
6 = 0.7782
a. c. 4 = 9.3979
11
0.4683 = 2.94

l = 8.06 = 0.9063
log. Vol. B = 2.6086

3.5149 = 32

(C)

$\frac{7}{4}$ [Same as (B)]

0.2992
log 7 = 0.8451
a. c. 4 = 9.3978

0.5421 = 3.48
11

l = 14.48 = 1.1608
log Vol. (C) = 2.6775

3.8383 = 6892.

(D)

$$\frac{7.6}{4}\left(\frac{3\times 56.3+2\times 9\times 7.5+81}{56.3+\quad 9\times 7.5+81}\right.$$

Same as (A).

0.2727
7.6 = 0.8808
a. c. 4 = 9.3978

0.5515 = 3.56
18

21.56 = 1.3336
log Vol. (D) 2.6099

3.9435 = 8780.

(E) Cylinder.

Vol. 389 × 30 = 11670.

(F)

$$\frac{13.3}{4}\left(\frac{3\times 36+2\times 6\times 6.5+42.3}{36+\quad 6\times 6.5+42.3}\right.$$

3	6	39
		36
108	39.0	
78	2	117.3
42.3		
	78	

228.3 = 2.3585
2.0697

0.2888
13.3 = 1.1239
a. c. 4 = 9.3978

0.8105 = 6.464
34.40

l = 40.86 = 1.6117
log Vol. (F) = 2.6115

4.2232 = 16720.

(G)

$$\frac{40}{4}=10\left(\frac{3\times 21.2+2\times 4.6\times 5.2+27}{21.2+\quad 4.6\times 5.2+27}\right.$$

3	4.6	23.92
		21.2
63.6	312	
47.8	208	72.12
	23.92	
	2	
	47.84	

$\frac{27}{138.44} = 2.1412$
1.8580
0.2832
log 10 = 1
1.2832 = 19.2
47.7
l = 66.9 = 1.8254
log Vol. (G) = 2.8778
4.7032 = 50490.

(H) **Cylinder:**
Vol=30.6 =1.4857
l=88.45=1.9467
3.4324=2706

87.7
.75
88.45

Negative moments.

Chamber volume= 104.24
11
10424
10424
1146.64=1146.64

Bore.
l=2)73.2
36.6
16

Volume=588.71=2.7699
52.60=1.7210
4.4909=30960
32106.64

Moments. A= 713
B= 3273
C= 6892
D= 8780
E=11670
F=16720
G=50490
H= 2706
101244

Moment of bore=32107

69137 Log=4.83971
2446 Log=3.38846

1.45125=28.265

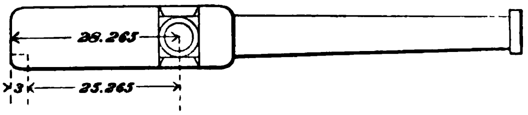
Volumes. A+B+C+D=1555.4
E= 389.
F= 409.
G= 755.
H= 30.6

3139. Volume of piece as solid.
692.95 Volume cham. and bore.

2446.

Preponderance, 50 pounds.

PROJECTED STEEL 3."2 B. L. R.



Formula=$y=\frac{p}{w\ p}\,l$

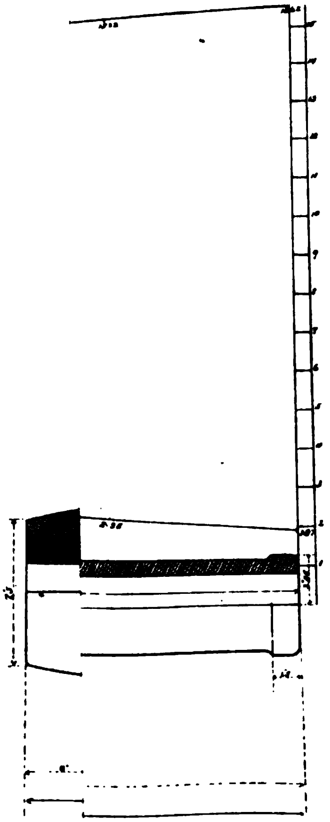
W−p=696.47−50=646.47 a. c.=7.18945
p=50=1.69897
l=25.265=1.40252

0.29094

1.95
28.26

Position of trunnions for prep. of 50 pounds=30.21

PLATE I.



Appendix 31—1883.

U. S. Ordnance Board
Governors Island April 6th 1883.

APPENDIX 32.

TRIAL OF A NEW STEEL FIELD CARRIAGE FOR THE 3.2-INCH BREECH-LOADING RIFLE.

(2 plates.)

This trial was directed by the first indorsement of the Chief of Ordnance on Ordnance Office file No. 2999, of 1883. The carriage made at Watervliet Arsenal was received June 26, 1883. A drawing showing the carriage in plan and longitudinal vertical section accompanies this report.

The wheels of the carriage were made by the Archibald Company, and have 16 spokes.

The trail is composed of two steel plates each five-sixteenths (0.312) of an inch thick, with angle steel riveted to the upper and lower edges. The plates are connected by four transoms, an assembling bolt, and the heavy lunette plate. One transom is in front and a second is in rear of the cheeks, a third is in rear of the elevating apparatus, while a fourth lies beneath this apparatus, is bolted to the angle steel, and is slotted for the passage of the elevating screw. The last two transoms give strength to the part of the trail that is most severely strained in firing. The assembling bolt passes through the cheeks and plates, below the trunnion beds, and assists the transoms attached to the cheeks in resisting a tendency to spread. Between the plates is a tool chest. The cheeks are heavy castings of steel, which are fitted to the inside of the trail plates, and are riveted to them. The trunnion bed plates form a part of the cheeks; they overlap and rest upon the plates. Each trunnion bed plate has screwed into it a hook and keyed pin to hold the cap squares in place. The trail handspike, a metal tube, is permanently attached to the trail and rests in a Y, which retains it in position when the carriage is limbered up.

The axle is novel in construction, being composed of a steel axle-tree three inches in diameter, reinforced by two steel plates three-eighths inch thick, each of which contains a groove of such dimensions that when the plates are applied to the axle-tree and riveted together they embrace it with a firm contact throughout its whole length. They project in front and in rear of the axle-tree, and give to the axle the structure of a solid built beam with its depth in the direction of the greatest strain, and the stiffness necessary to resist the shocks due to recoil. Heretofore in firing the rifled field gun the inertia of the wheels has caused the axle to bend after a few rounds. Five hundred and seventy-four rounds have been fired from a carriage furnished with an axle similar to the one just described, without injury to the axle, and it is believed that this arrangement, due to Lieutenant Colonel Buffington, of the Ordnance Department, will be found amply strong.

The brake is peculiar to this carriage, and was devised by Lieutenant

Colonel Buffington. Each axle shoulder is furnished with an eye, to which is attached a brake composed of two rods, one of which has at its end an eye to connect it with that in the axle-shoulder, thus forming a universal joint; its other end is screwed into a sleeve or housing inclosing a stout spiral spring. One extremity of the other rod passing through the spring terminates in a nut to bear against the spring, while the other extremity terminates in a shoe which can be brought into contact with the tire. The length of the brake is such that when held at an angle of 45° it passes freely over the tire; if it then be dropped toward the trail it assumes a position of about 12° above a horizontal line, and when the carriage recoils, the spring allows the rod to be drawn out until the brake making an angle 22° below the horizontal, firmly locks the wheel, without unduly straining it. It may be remarked that a solid rod used on a similar carriage did not give as good results as the spring brake. In running the carriage forward by hand after firing, the wheels are automatically and easily unlocked. If instead of dropping the brake toward the trail it be allowed to fall toward the muzzle of the gun, it will rise and fall when the carriage is traveling, and act as a mud-scraper.

The elevating apparatus designed at Watervliet Arsenal has the double screw (described in the report of the Chief of Ordnance for 1880, page 45) elevated and depressed by a hand wheel, which actuates a level gear. The support for the screw and its gearing is a bronze casting having trunnions which permit rotation in a plane passing through the axis of the carriage. The head of the elevating screw is directed and sustained in this plane by a brace composed of two rods, each pivoted at one end on a trunnion projecting from the head, and at the other end pivoted upon a screw-bolt passing through the cheeks.

The trial of this carriage took place at Sandy Hook, June 27 and 28. Ten Hotchkiss projectiles were fired at an angle of 3°, the carriage being carefully examined after each shot. Everything worked well except that the tubular trail handspike began to bend from its own inertia. The gun was then fired ten additional rounds under an angle of 20°, the carriage only admitting of 21° elevation. The trail handspike continued to bend gradually; the guide-rods for the head of the elevating-screw separated slightly at their junction with the trunnions of the head; the right-hand brake-rod showed an incipient fracture near the eye, apparently at a weld, although whether a weld existed at this point or not could not be definitely ascertained. Two rounds fired after the fracture was discovered did not cause any increase of the ruptured surface. The efficiency of the brake in checking recoil is marked, as without it the carriage recoiled from 24 to 26 feet when fired from a platform, while with it the recoil was but 8 feet.

In conclusion the Board would report that a similar carriage successfully endured, so far as the axle and brake were concerned, 574 rounds, and the present carriage is amply strong for all the requirements of the service. No further trials with this particular carriage are considered necessary, as it was constructed in such a manner as to remedy defects existing in the first steel carriage furnished from Watervliet Arsenal, which, as has already been stated, has been subjected to 574 rounds. The Board therefore would state that in its opinion the carriage is fitted for the requirements of the service so far as strength to resist the shocks due to firing and observation at the proving-ground can determine it, except in the following respects, viz:

(1.) The trail handspike is too light, and while the method of attachment is considered the best yet submitted to the Board, it is believed that a wooden handspike with the same attachment would not be susceptible to bending from its own inertia and would be easier to handle.

(2.) The brakes should not terminate in an eye, but in a hook with a link over the opening to secure it. Thus arranged it may be more readily replaced if injured.

(3.) The guide rods for the head of the elevating screw should be prevented from separating at their junction with the trunnions. This was effected here by "burring" up the ends of these small trunnions projecting from the head.

(4.) It is not known whether or not the brakes are intended as a substitute for the chain in locking the carriage when passing over a declivity. If so, it is thought that there may be difficulty in releasing them, as is usually done when near the end of the descent; that it may be necessary for this purpose to stop and back the carriage, which would be a troublesome operation in any case, and impracticable if several carriages were in column.

In carriages to be made after those now in process of construction are completed it is believed that axle plates five-sixteenths of an inch in thickness should be substituted for those three-eighths thick, now used, as the present carriage, without seats for cannoneers, and without the necessary implements, weighs about 1,220 pounds. The thinner plates are amply strong and their use would diminish the weight.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 3.20-inch breech-loading rifle, No.

[Chambered.]

	Number of fire.	Time.	Powder.		Projectile.		Elevation in degrees.	Deflection.			
			Kind.	Weight.	Kind.	Weight.		Range, yards.	Right, yards.	Left, yards.	
		1883.		*Lbs.*		*Lbs.*	°				
Barometer, 29.953; thermometer, 67; humidity, 100; wind, 37 miles an hour.	830	June 27	Du Pont's I. K. B. Density, 1.725; granulation, 2200.	3	Hotchkiss rebanded, 1 copper band.	12	3	a	....	....	Carriage on plank road and planks wet from rain storm.
	831	June 27		3		12	3	....	....	....	
	832	June 27		3		12	3	....	....	....	
	833	June 27		3		12	3	....	....	....	
	834	June 27		3		12	3	....	....	....	
	835	June 27		3		12	3	....	....	....	
	836	June 27		3		12	3	....	....	....	
	837	June 27		3		12	3	....	....	....	
	838	June 27		3		12	3	....	....	..	
	839	June 27		3		12	3	....	....	....	
Barometer, 29.967; thermometer, 76; humidity, 69; wind, 12 miles an hour.	840	June 28		3		12	20	6,001	98	....	Carriage on plank road and planks dry.
	841	June 28		3		12	20	....	....	....	
	842	June 28		3		12	20	5,860	16	....	
	843	June 28		3		12	20	6,036	....	37	
	844	June 28		3		12	20	5,612	2	....	
	845	June 28		3		12	20	5,659	3	....	
	846	June 28		3		12	20	....	....	....	
	847	June 28		3		12	20	....	....	....	
	848	June 28		3		12	20	5,892	....	7	
	849	June 28		3		12	20	6,096	2	....	

774, at Sandy Hook, N. J., from June 27 to June 28, 1883.

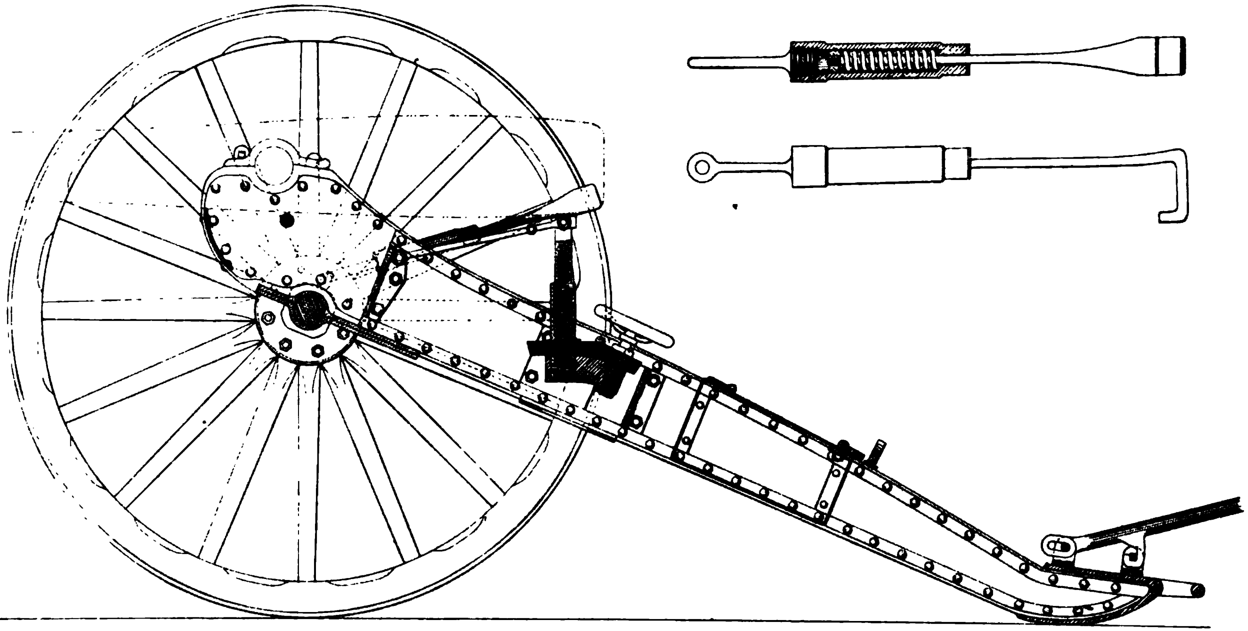
[Chambered.]

Recoil, feet.	Direction of wind as regards line of fire.	Counter recoil, feet.	Direction and strength of wind.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
12.58	From left to right.	....	From front and left, 45°; 37 miles an hour.	Experimental steel gun carriage from Watervliet Arsenal with trail-plate strengthened with steel angle-plate. Fired into sand butt to try carriage. Rounds 830 and 831 trail-handspike left forward on trail; in following rounds, trail-handspike left down in position for maneuvering. After round 839 it was noticed that trail-handspike was slightly bent. Straightened before firing round 840 and left down during following rounds; trail-handspike commenced bending again at round 841, curvature slightly increasing at each succeeding round.
14.00		1.50		
14.42		1.58		
14.00		1.58		
14.33		1.25		
15.00		1.58		
14.50		1.58		
15.00		1.50		
13.33		1.58		
15.83		1.58		
4.50	From right to left.	1.00	From front and right, 65°; 12 miles an hour.	Brakes over tire of wheels forced down.
4.67		1.00		
4.50		1.00		
4.83		1.17		
5.17		1.00		Fired over water. Brakes over tire of wheels easy. At round 847 right brake rod cracked at weld in neck.
5.33		1.42		
5.17		1.00		
5.25		1.17		
5.17		1.33		
5.08		1.17		

For the Board.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.

STEEL FIELD CARRIAGE FOR 3·2 INCH B. L. RIFLE

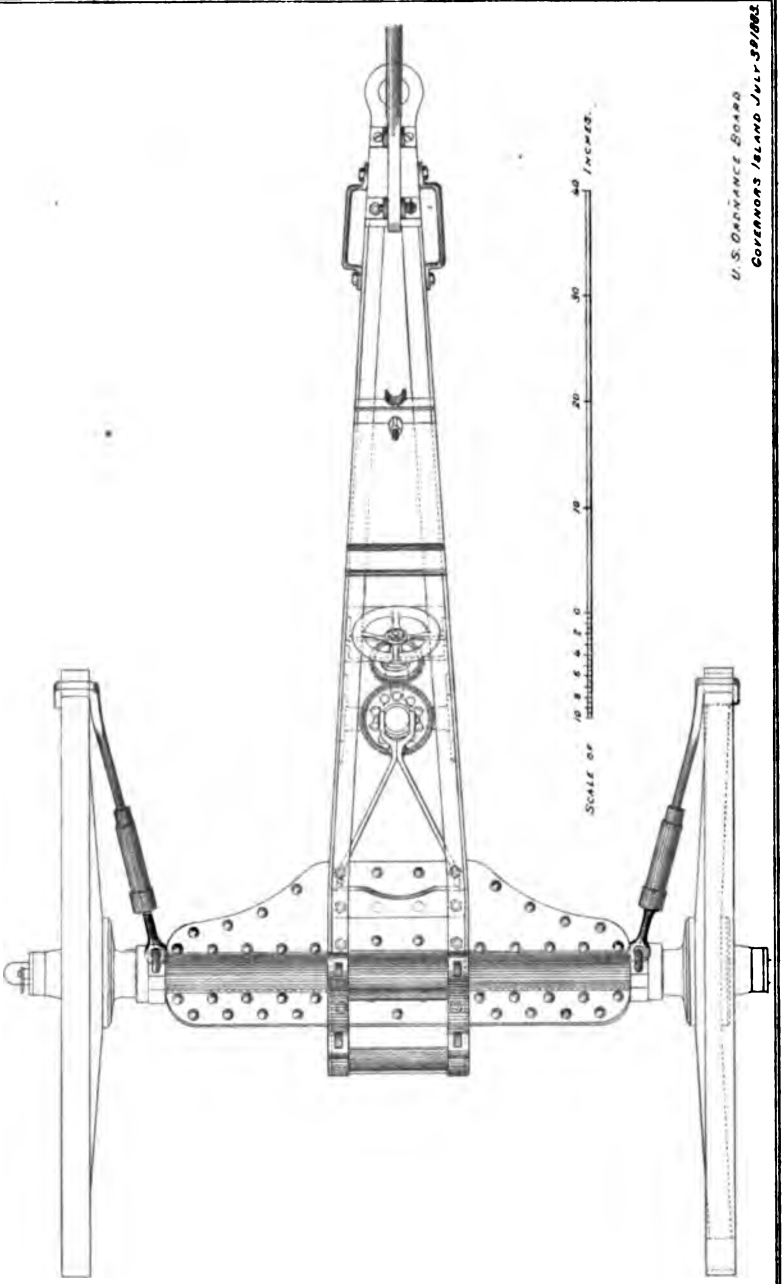


SCALE OF 10 8 6 4 2 0 10 20 30 40 INCHES.

U.S. ORDNANCE BOARD
GOVERNORS ISLAND JULY 3d/1883.

PLATE II.

STEEL FIELD CARRIAGE FOR 3·2 INCH B. L. RIFLE



Appendix 33—1883.

APPENDIX 33.

TRIAL AND TEST OF A 3.2-INCH BREECH-LOADING RIFLE AND CARRIAGE.

(2 plates.)

The first indorsement on Ordnance Office file No. 4480 of 1882 directed that a 3.2-inch converted rifle should be fired six hundred rounds with three-pound charges, that the firing to test a new field-carriage should be included in the test of the gun, and that firing with a reduced charge of 2½ pounds should be made with the gun mounted on a wooden carriage of the service pattern.

The gun used was a piece at first converted to 3.19 inches caliber, but afterwards ground out to 3.2 inches, and was originally numbered 774, a number which has been retained. A description and drawing of the piece and its breech mechanism are given in Appendix 8 a of the Report of the Chief of Ordnance for 1880, at pages 42 *et seq.* On September 30, 1881, a report was made of two hundred and fourteen rounds, generally with two-and-a-half-pound charges, fired up to that time. This appears in the Report of the Chief of Ordnance for 1881, pages 503 *et seq.* Subsequently the proof with three-pound charges, as above directed, was carried on.

The steel carriages, two in number, were received at different times from Watervliet Arsenal. In the first the trail plates were strengthened by flanges formed by turning in the upper and lower edges of the plates themselves. In the second the upper and lower edges of the plates were reinforced by angle steel riveted to them.

For convenience the carriage with flanged plates will be denominated No. 1, and that with riveted angle plates will be called No. 2.

CARRIAGE NO. 1.

(Plates I and II.)

The trail is composed of two plates of steel deepened at the part supported by the axle to conform to the cheeks. The upper and lower edges are flanged inward by heating the plates and turning down the edges under the hammer as is done with boiler-heads. This increases the rigidity of the system. The plates are connected by three transoms, an assembling bolt, and the lunette plate. One transom is in front of the cheeks and riveted through the flange; a second is in rear of the cheeks and is riveted through the plates; a third, also riveted through the plates, is found just in rear of the axle for the hand wheel which actuates the elevating gear. The assembling bolt is placed beneath the trunnion beds, and is curved in order that its points of attachment may be as high as possible without interfering with the laying of the piece.

The cheeks are heavy castings of steel, fitted to the inside of the trail plates, and each bears a trunnion bed which projects over the plate and rests upon it. Each trunnion bed has a hook and key bolt fitted to it for holding the corresponding cap square in place. The trail handspike is a metal tube permanently affixed to the trail by means of an eye at its end which fits in a corresponding one in the lunette plate. A link attached to the handspike engages in a hook fixed to the lunette plate when it is desired to lift the trail. When the piece is to be limbered up the link is disengaged and the handspike may be turned towad the muzzle until it lies parallel to the trail and is there supported byra rest provided for the purpose.

The axle is formed of an axle-tree and two axle-plates. The axle-tree is made of steel, the arms having the usual conical form, but between the shoulders the tree is turned down to a diameter of 3 inches. Two steel plates, each five-sixteenth inches thick, are grooved to fit the tree and when riveted together embrace it firmly. The plates increase in depth both in front and rear toward the central line, giving a greater resistance where the strain is greatest.

The brake is of a new kind and requires a detailed description. Two different models were furnished with this carriage, one called a solid brake, the other a spring brake. Each solid brake is composed of a rod enlarged at one end to form a shoe, bent in order to bear firmly upon the tire when the wheel revolves in recoiling; the other end of the rod terminates in a hook closed by a link, the hook engaging in an eye upon a band shrunk over the axle. Each spring-brake is composed of two rods, the first of which has an eye at one end to connect it with the eye on the axle shoulder; at the other end it is screwed into a sleeve which contains a strong spiral spring. One extremity of the second rod passes through the spring and terminates in a nut of the same diameter as the exterior surface of the spring, while the other extremity terminates in a shoe. The lengths of the rods for either form of brake are such that when the brake is held up at an angle of 45° the shoe passes freely over the tire; if it be then dropped to the rear the shoe lies lightly against the tire until recoil takes place, when the contact becomes so firm as to securely lock the wheel. If, when passed over the tire, the shoe is pushed toward the muzzle of the gun, it rises and falls when the carriage is traveling and acts as a mud scraper. It may be here stated that the shoe of the solid brake commenced to bend during the firing, and the spring brake when substituted showed no signs of yielding, therefore the solid model was rejected.

The elevating apparatus consist of (1) a screw lying between the trail-plates and parallel to their lower edges, given a motion of rotation by bevel gear operated by a hand wheel, and fixed as to motion of translation; (2) a nut which is given a longitudinal movement by this screw and has a lug upon its upper surface, to which lug a rod is jointed by a pivot; (3) the rod above referred to which at the end remote from the pivot passes into a seat affixed to the breech and thus supports the gun. When the nut is retracted the piece is depressed. When it is pushed forward the preponderance causes the breech to follow and the muzzle is elevated. To secure as great an elevation as possible, the flanges of the trail-plates were cut out in a curve to admit the reinforce of the gun, and at a point shown in the plan the flange was entirely removed to leave the projecting portion of the breech block freedom from contact with the trail.

The trial of carriage No. 1 commenced April 19, 1883, with round

215 of the accompanying firing record. The solid brake was applied at first, but after 17 rounds examination showed a crack in the left-hand brake at the outer angle of the shoe, moreover both shoes had been bent backward. The spring-brake was then substituted and subjected to 557 rounds which it endured without injury, while the recoil was two-thirds less than when no brakes were used, as is shown by the fact that without the brakes a distance of 26 to 28 feet was traversed, while with them this distance was reduced to from 7 to 8 feet.

The elevating apparatus gave trouble from the beginning, and at the seventeenth round it was permanently injured by the bending of the screw, and was replaced during the subsequent firing by a quoin. The trail plates commenced to yield near the position of the elevating apparatus until they were so bent as to render it necessary to replace the transom at this point by a heavier one, and side plates were bolted to the inner part of each trail plate at the same point. No further spreading was observed afterwards, and it is believed that the injury was due to the cutting away of the flange to allow high elevation.

The cap squares were too light, as were also the bolts which secured them to the trunnion bed plates. The squares and bolts were replaced by heavier ones, which were not affected by the shocks of firing and recoil. The axle showed no signs of yielding, and is considered competent to resist all shocks due to recoil, which when firing with this light gun, having a preponderance of about 80 pounds, must be very considerable. A pencil resting against a vertical board, and pressed into contact with it by a spiral spring, was fastened to the trail and a similar device was appended to the end of the axle-arm. These traced the paths in which the end of the trail and the arm moved. The carriage was placed on a hard sand plane during that part of the firing when these tracings were obtained. It appeared that at the first instant of recoil the wheels and trail were pressed hard against their points of support; that then both rebounded from the earth, and that for a certain time the gun and carriage were in the air; that descending the wheels struck the ground first, followed by the trail. This movement brought the breech of the gun down with violence upon the head of the elevating screw, and to the violent shock, enhanced by the preponderance of the piece, the injury to the elevating apparatus was due. An axle and spring brakes, similar to the one which gave such good results in this carriage, were applied to the new one furnished later from Watervliet Arsenal. The cap squares and transoms were strengthened on the latter carriage, a new elevating apparatus was supplied, and the flanges were replaced with steel angle riveted to the edges.

CARRIAGE NO. 2.

This carriage has been fully described in Ordnance Board Report No. 8, forwarded July 3, 1883, so that no further description is deemed necessary.

The trial was also reported upon, and it will suffice here to say that in this carriage defects that had existed heretofore seem to have been overcome. A few changes in minor details were recommended.

THE WOODEN CARRIAGE.

The trials directed to be undertaken with a wooden carriage of the regulation pattern, when charges of two and a half pounds were fired from the gun, commenced with round 262 of the accompanying record November 24, 1882, when the gun was mounted on a carriage that had been received from Watervliet Arsenal, October 17, 1882. At the second round a bolt holding the axle-strap broke and was replaced before firing again. At the third round the stock broke 14 inches from the axle, the wood showing evidence of dry rot. The gun was then mounted on a wooden carriage, having a new stock furnished from Watervliet Arsenal in the rough, but finished and fitted at Sandy Hook. Twenty-five rounds were fired from this carriage, the last ten under 13° elevation, without injury, but the recoil on the plank road which supported the carriage was from 21 to 30 feet. A spring brake similar to that previously described was fitted, and thirteen more rounds were fired, the recoil being reduced to 10 feet. This total of thirty-eight rounds showed that a perfectly sound wooden carriage may be safely used if the charge does not exceed two and a half pounds of I. K. powder. A report was made on this subject November 29, 1882.

The trial of the gun with 3-pound charges was commenced systematically with round 215, on April 19, 1882. The preceding rounds were fired principally with charges of 2½ pounds, and, as stated before, the records of these rounds were published in the Report of the Chief of Ordnance for 1881. Two different breech blocks were used, one with a pressure plug inserted in the base, and the other of the usual form. The first one, having its own gas check and obturator plate, was inserted only when pressures were to be determined:

The following table shows the repairs made to the breech mechanism of the block containing the pressure plug and the number of rounds fired with it.

Rounds.			Remarks.
2½-pound or less charge.	3-pound charge.	Total.	
No.	*No.*	*No.*	
27	18	45	Gas check reseated.
......	24	69	Escape of gas all around check.
......	1	70	Do.
......	1	71	Do.
......	11	82	Face of gas check ground down to remove gas cuts and a new obturator plate put in.
......	17	99	Examination showed that gas check and obturator plate had been scored during the previous ten rounds.
......	5	104	
27	77	......	Total.

The following table is for the solid breech block:

Rounds.			Remarks.
24-pound or less charge.	8-pound charge.	Total.	
No.	*No.*	*No.*	
178	24	202	Slight escape of gas around gas check; breech block would not close and *gas check* was changed.
....	1	203	Very slight escape of gas.
....	1	204	No escape of gas.
21	255	480	Gas check shows cuts in four different places across first canneluro and partly into second, which cuts were developed in the last 10 rounds.
....	9	489	Gas check showed no material change in last 10 rounds.
....	9	498	Gas cuts deepened slightly; the face of check was ground until cuts were obliterated and a new *obturator plate* was put in place.
....	63	561	Examination showed that the gas check had been scored during the preceding 10 rounds, and it was ground off before continuing firing.
....	9	570	Examination showed that the gas check had been scored during the preceding 10 rounds, and it was ground off before continuing firing.
....	9	579	Examination showed that the gas check had been scored during the preceding 10 rounds, and it was ground off before continuing firing
....	9	588	Examination showed that the gas check had been scored during the preceding 10 rounds, and it was ground off before continuing firing.
....	45	633	Examination showed that the gas check and obturator plate had been scored during the preceding 10 rounds.
....	54	687	Gas cuts show in six different places on face of gas check. One crossing all the cannelures to the outside edge. These cuts are enlargements of those previously reported. The face of the gas check has been ground off three times during the last seventy rounds. A new gas check and vent were then fitted to the gun.
....	58	745	

An examination of the above tables shows that the gas check with the first block showed signs of wear at the forty-fifth round, when the seat had to be ground down. At the eighty-second round a new obturator plate was required, and even with this change the gas continued to escape sufficiently to injure the check and the plate.

The second block was evidently more carefully fitted originally, and no injury appeared until round two hundred and two, when the block would not close and a new check was fitted. Two hundred and seventy-six rounds were fired with this new check before any material injury occurred, after which the cuts made by the gas gradually increased so that the obturator plate had to be removed and the check and plate had to be ground down to obliterate the cuts. As the last table shows, in firing 745 rounds the obturator plate was renewed once and the gas check twice, and the second gas check was ground down eight times after it once commenced to yield perceptibly, that is, after it had endured 359 rounds. It is probable that owing to the frequent changing of the blocks injuries were more likely to occur in this proof firing than would be the case in actual service. Two gas checks are provided for each converted gun, and from the indications given by those already used it seems at least probable that a gas check can be relied upon for about 300 rounds.

At round 440 a flaw was detected in the bore of the gun during the star gauging. Impressions of the bore were taken with rubber and showed four cavities in the upper right-hand side of the bore, one at 10.5 inches, one at 11.5 inches, a third at 29.5 inches from the muzzle, and a fourth in the immediate vicinity of the latter. The cavity at 29.5 inches was the deepest and its exact size could not be measured, as the plastic substance was marred slightly when the rubber was withdrawn, but as nearly as could be determined the depth of the cavity was 1.125 inches. It appeared to be due to a defective weld eroded by the action of the powder charge. There was no apparent increase in the depth of this or the other cavities, nor did any new one appear during the remainder of the firing, that is, during 409 additional rounds; furthermore, these defects exercised no appreciable influence on the accuracy of flight of the projectiles.

The following table summarizes the results of firing with 3-pound charges and 12-pound solid shot:

Total number of 3-pound rounds with I. K. powder		623
Pressure in bore (mean of 66 rounds)	pounds per square inch	25,644
Instrumental velocity (mean of 62 rounds)	feet	1,530
Muzzle velocity	do	1,545

Muzzle energy.

Total.	Square inch shot's cross-section.	Per pound of powder.	Per pound of piece.	Factor of effect.
Foot-tons. 199.6	*Foot-tons.* 17.87	*Foot-tons.* 66.53	*Foot-pounds.* 541.2	*Per cent.* 71.77

Range table with 12-pound Hotchkiss shot and 3-pound charge of I. K. powder.

Angle of fire.	Range.		Time of flight.	
	Yards.	Difference.	Seconds.	Difference.
5°	2,508	1,478	7.56	5.53
10°	3,986	992	13.19	5.21
15°	4,978	901	18.4	5.0
20°	5,879		23.4	

T. G. BAYLOR,
Colonel of Ordnance,
President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 3.20-inch breech-loading rifle No. 774, chambered,

[By Major A. Mordecai,

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.		Elevation.	Pressure per square inch of bore.	Instrumental velocity 90 feet from gun.	Recoil.
		1882.		*Lbs*		*Lbs.*	*Oz.*	°	*Lbs.*	*Feet.*	*Feet.*
	215	Apr. 19	Du Pont's I. K. A. Density, 1.725; granulation, 2,200.	3	Hotchkiss hollow shot.	12	11	6	....	....	5.83
	216	Apr. 19		3		12	11	6	....	....	7.00
	217	Apr. 19		3		12	11	6	....	....	5.83
	218	Apr. 19		3		12	11	6	....	....	6.25
	219	Apr. 19		3		12	11	6	....	....	5.25
	220	Apr. 19		3		12	11	....	....	....	6.50
	221	Apr. 19		3		12	11	....	....	....	5.25
	222	Apr. 19		3		12	11	....	....	....	6.67
	223	Apr. 19		3		12	11	13	....	....	7.00
	224	Apr. 19		3		12	11	13[illegible]	....	....	6.50
	225	Apr. 19		3		12	11	13[illegible]	....	....	6.17
	226	Apr. 19		3		12	11	2	....	....	7.50

AT SANDY HOOK, N. J., FROM NOVEM

[Gun mounted on

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.		Elevation.	Pressure per square inch of bore.	Instrumental velocity 90 feet from gun.	Recoil.
P. M.—Barometer, 29.909; thermometer, 41; relative humidity, 48; wind, 5 to 1 miles an hour.	227	Nov. 21	Du Pont's I. K. A. Density, 1.725; granulation, 2,200.	3	Hotchkiss cored shot (lot 29).	12	00	0	Pressure gauge in breech block. Rectangular disk area of piston, 0.1 sq. inch.	1,502	8.00
	228	Nov. 21		3		12	00	0		1,488	8.00
	229	Nov. 21		3		12	00	0		1,493	8.00
	230	Nov. 21		3		12	00	0		1,498	7.83
	231	Nov. 21		3		12	00	0		1,496	8.08
	232	Nov. 21		3		12	00	0		1,482	8.00
	233	Nov. 21		3		12	00	0		1,491	8.00
A. M.—Barometer, 29.930; thermometer, 36; relative humidity, 65; wind, 20 miles an hour.	234	Nov. 22		3		12	00	0	37,500	1,493	7.92
	235	Nov. 22		3		12	00	0	85,000	1,492	7.92
	236	Nov. 22		3		12	00	0	85,000	1,497	8.25
	237	Nov. 22		3		12	00	0	85,000	1,508	8.25
	238	Nov. 22		3		12	00	0	35,500	1,509	8.08

at Watervliet Arsenal, from April 19, 1882, *to April* 19, 1882.

test carriage of metal, &c.]

Direction of wind as regards line of fire.	Circumference of cartridge-bag.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
	Inches.		
....	....	Each held vertical before firing by being wired to a spoke, and thus kept from contact with wheel till after recoil began.	Right bolt attaching elevating fixture to gun broke off. Slight distortion of trunnion plates and cap squares.
....	....		Left bolt attaching elevating fixture to gun broke off, rendering elevating apparatus useless. Distortion of cap squares increased. Right brake fell off wheel.
....	....		
....	....		
....	....	Each placed in contact with wheel before firing.	Distortion of cap squares increased.
....	....		
....	....		
....	....		
....	....		
....	....		
....	....		
....	....		The three rivets attaching left trunnion plate to cheek were sheared off.

BER **21, 1882,** ***TO JUNE*** **28, 1883.**

iron carriage.]

From rear.	10.65	Spring brake on carriage.	Fired into sand butt. Gun on plank road.	Elevating bar slipped out of its socket; rope passed around gun and under carriage to prevent rebounding of gun.
	10.73			
	10.70			Cap square pins bent.
	10.51			
	10.65			Elevating screw bent in box.
	10.75			Elevating screw-bar and boxes removed; block fitted in and elevation given with a quoin.
	10.70			
	10.60	Solid brake on carriage.		Before firing round 234, breech block was changed for one with a pressure plug, made at Sandy Hook.
	10.58			
	10.50			
	10.70			
	10.55			

An examination made after firing the 238th round showed that the carriage had spread about midway between the front transom and that through which elevating screw passes. Left-hand brake found to have been cracked. Before continuing the firing carriage taken to shop and extra transom put in where carriage had spread and side plates bolted on inside of trail on both sides, running before and behind this extra transom.

Record of firing with 3.20-inch breech-loading rifle No.

	Number of fire.	Time.	Powder.			Projectile.		Elevation.	Pressure per square inch of bore.
			Kind.	Weight.		Kind.	Weight.		
		1882.		Lbs.	Oz.		Lbs.	°	Lbs.
A. M.—Barometer, 30.114; thermometer, 43; relative humidity, 68; wind, 4 miles an hour.	239	Nov. 23	Du Pont's I. K. A. Density, 1.725; granulation, 2,200.	3	00	Hotchkiss cored shot (lot 29).	12	0	Pressure-gauge in breech-block. Rectangular disk. Area of piston, 0.1 square inch.
	240	Nov. 23	do	3	00		12	0	
	241	Nov. 23	do	3	00		12	0	
	242	Nov. 23	do	3	00		12	0	
	243	Nov. 23	do	3	00		12	0	
	244	Nov. 23	do	3	00		12	0	
	245	Nov. 23	do	3	00		12	0	
P. M.—Barometer, 30.028; thermometer, 47; relative humidity, 72; wind, 5 miles an hour.	246	Nov. 23	do	3	00		12	5	
	247	Nov. 23	do	3	00		12	5	
	248	Nov. 23	do	3	00		12	5	
	249	Nov. 23	do	3	00		12	5	
	250	Nov. 23	do	3	00		12	5	
A. M.—Barometer, 29.922: thermometer, 40; relative humidity, 82; wind, 32 miles an hour.	251	Nov. 24	do	3	00		12	10	
	252	Nov. 24	do	3	00		12	10	
	253	Nov. 24	do	3	00		12	10	
	254	Nov. 24	do	3	00		12	10	
	255	Nov. 24	do	3	00		12	10	
A. M.—Barometer, 29.894; thermometer, 43; relative humidity, 51; wind, 36 miles an hour.	256	Nov. 24	do	3	00		12	15	
	257	Nov. 24	do	3	00		12	15	
	258	Nov. 24	do	3	00		12	15	
	259	Nov. 24	do	3	00		12	15	
	260	Nov. 24	do	3	00		12	15	
	261	Nov. 24	do	3	00		12	20	
P. M.—Barometer, 29.901; thermometer, 43; relative humidity, 65; wind 40 miles an hour.	262	Nov. 24	do	2	08		12	0	24,500
	263	Nov. 24	do	2	08		12	0	24.500
	264	Nov. 24	do	2	08		12	0	25,500
P. M.—Barometer, 29.928; thermometer, 43; relative humidity, 64; wind, 36 miles an hour.	265	Nov. 24	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	00		12	0	39,500
	266	Nov. 24	do	3	00		12	0	40,000
A. M.—Barometer, 30.185; thermometer, 38; relative humidity, 54; wind, 25 miles an hour.	267	Nov. 25	Du Pont's I. K. A. Density, 1.725; granulation, 2,200.	2	08		12	0	28,000
	268	Nov. 25	do	2	08		12	0	24,000
	269	Nov. 25	do	2	08		12	0	24,500
	270	Nov. 25	do	2	08		12	0	27,000

774, chambered, at Sandy Hook, N. J., &c.—Continued.

Instrumental velocity 87 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Time of flight.	Range.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Feet.	*Feet.*		*Seconds*	*Yards.*		
....	4.75	From right and front.	....	....	Fired into sand butt. Gun in sand.	Slight escape of gas around gas-check.
....	5.08		....	....		Breech-block would not close and gas check was changed. Very slight escape of gas around gas check.
....	5.00		....	....		No escape of gas. Cap-square stud on right side found partially broken; this found broken still more after 244th round and completely broken at 245th. Both studs then removed, holes tapped to 1 inch, and studs from another carriage put in. (Old holes were ¾ inch.)
....	4.67		....	....		
....	4.83		....	....		
....	4.83		....	....		
....	4.83		....	....		
1,486	5.67		....	2,554	Fired over water for ranges. Gun on plank road.	
1,481	5.67		....	2,502		
1,500	5.83		8	2,496		Angle-iron on left cheek of carriage started.
1,489	5.58		8¼	2,502		
1,496	5.50		8⅜	2,554		
75 *feet.*						
1,487	5.58	From rear and right.	13	4,193		
1,497	6.33		....	4,135		
1,490	5.75		13	4,017		
1,496	5.75		13¼	Lost.		
1,502	6.00		....	4,217		
1,494	4.50		18½	5,220		
1,499	4.50		18¾	5,220		
1,500	4.50		18½	5,090		
1,486	5.17		18¼	5,090		
1,501	4.83		....	5,170		
62 *feet.*						
1,508	5.50		Lost.	Lost.		
90 *feet.*						
1,342	26.00		....	....	Fired into sand butt. Gun on plank road.	Before firing round 262 gun dismounted from iron carriage and mounted on wooden carriage received from Watervliet Arsenal October 17, 1882.
1,319	26.00		....	....		Bolt holding middle axle-band broke; replaced before firing again.
1,338	21.33		....	....		Stock broke 14 inches from axle. Wood showed plainly evidence of dry rot.
1,542	8.00		....	....		Before firing round 265 gun dismounted from wooden carriage and mounted on its iron carriage and with spring brakes. Bolt fastening plate to trail broke; replaced before firing again; imperfect, showing partial fracture after breaking.
1,534	8.00		....	....		
1,343	26.58		....	....		Before firing round 267 gun dismounted and mounted on wooden carriage, having new stock furnished from Watervliet Arsenal and finished and fitted at Sandy Hook.
1,320	27.50		....	....		
1,324	27.25		....	....		
1,329	27.00		....	....		

Record of firing with 3.20-inch breech-loading rifle No.

	Number of fire.	Time.	Powder.			Projectile.			
			Kind.	Weight.		Kind.	Weight.		Elevation.
		1882.		*Lbs.*	*Oz.*		*Lbs.*	*Oz.*	°
A. M.—Barometer, 30.231; thermometer, 40; relative humidity, 38; wind, 33 miles an hour.	271	Nov. 25	Du Pont's I. K. A. Density, 1.725; granulation, 2,200.	2	8	Hotchkiss cored shot (lot 29).	....		0
	272	Nov. 25	......do	2	8	....do	12	0	0
	273	Nov. 25	......do	2	8	....do	12	0	0
	274	Nov. 25	......do	2	8	....do	12	0	0
	275	Nov. 25	......do	2	8	... do	12	0	0
A. M.—Barometer, 30.231; thermometer, 40; relative humidity, 48; wind, 33 miles an hour.	276	Nov. 25	......do	2	8	Hotchkiss cored shot (resaboted).	12	0	0
	277	Nov. 25	......do	2	8	.. do	12	0	0
	278	Nov. 25	......do	2	8	.. do	12	0	0
	279	Nov. 25	......do	2	8	....do	12	0	0
	280	Nov. 25	......do	2	8	Hotchkiss cored shot (new).	12	0	0
	281	Nov. 25	......do	2	8	....do	12	0	0
	282	Nov. 25	......do	2	8	...do	12	0	13
	283	Nov. 25	......do	2	8	....do	12	0	13
	284	Nov. 25	......do	2	8	....do	12	0	13
	285	Nov. 25	......do	2	8	....do	12	0	13
	286	Nov. 25	......do	2	8	....do	12	0	13
	287	Nov. 25	......do	2	8	....do	12	0	13
	288	Nov. 25	......do	2	8	....do	12	0	13
	289	Nov. 25	......do	2	8	.. do	12	0	13
	290	Nov. 25	......do	2	8	....do	12	0	13
	291	Nov. 25	......do	2	8	....do	12	0	13

GUN MOUNTED ON IRON CARRIAGE

Barometer, 30.305; thermometer, 37; relative humidity, 89; wind 28 miles an hour.	292	Dec. 21	Du Pont's I. K. B. Density, 1,725; granulation, 2,200.	3	0	Hotchkiss cored shot.	....		0
	293	Dec. 21	......do	3	0	....do	12	0	0
	294	Dec. 21	......do	3	0	....do	12	0	0
	295	Dec. 21	......do	3	0	....do	12	0	0
	296	Dec. 21	......do	3	0	....do	12	0	0
	297	Dec. 21	......do	3	0	....do	12	0	0
	298	Dec. 21	......do	3	0	....do	12	0	0
	299	Dec. 21	......do	3	0	....do	12	0	0
	300	Dec. 21	......do	3	0	....do	12	0	0
	301	Dec. 21	......do	3	0	....do	12	0	0
	302	Dec. 21	......do	3	0	....do	12	0	0
	303	Dec. 21	......do	3	0	....do	12	0	0

774, chambered, at Sandy Hook, N. J., &c.—Continued.

Pressure, per square inch of bore.	Instrumental velocity 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Lbs.	*Feet.*	*Feet.*		
Pressure gauge in breech block. Rectangular disk. Area of piston 0.1 square inch.	....	27.00	From rear.	Gun on plank road. Fired into sand butt. Before firing 271st round breech block changed for solid breech block having no pressure-plug.
	....	27.00		
	....	28.00		
	....	28.00		
	....	26.00		
	....	29.00		
	....	27.00		
	....	27.00		
	....	28.00		
	....	30.00		
	....	26.00		
	....	21.00		Fired over water. Breech block taken out and cleaned; also face of gas-check.
	....	22.00		
	....	23.00		
	....	23.00		
	....	21.00		
	....	6.00		Gun in sand.
	....	6.00		
	....	6.00		
	....	6.00		
	....	6.00		Elevating screw box cracked.

MODIFIED BY LIEUT. COL. A. B. BUFFINGTON.

Pressure, per square inch of bore.	Instrumental velocity 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
26,500	1,523	7.00	From left to right.	Gun on plank road. Fired into sand butt. Spring brake connecting axle with tire of wheel by means of a shoe used to take up part of recoil. Before round 292 gas check reseated.
26,000	1,522	7.00		
28,000	1,535	7.00		
27,500	1,533	7.00		
27,000	1,542	7.50		
26,500	1,524	7.00		
25,500	1,522	7.00		
26,000	1,523	7.83		
26,500	1,527	7.00		
27,500	1,520	7.00		
27,000	1,527	7.00		
26,000	1,532	7.50		After round 303 breech block containing pressure-plug removed and solid breech block put in with corresponding gas check.

Record of firing with 3.20-inch breech-loading rifle No.

	Number of fire.	Time.	Powder.			Projectile.			Elevation.
			Kind.	Weight.		Kind.	Weight.		
		1882.		*Lbs.*	*Oz.*		*Lbs.*	*Oz.*	°
Barometer, 30.305; thermometer, 37; relative humidity, 89; wind 28 miles an hour.	304	Dec. 21	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	0	Hotchkiss cored shot.	12	0	0
	305	Dec. 21	......do	3	0	....do	12	0	0
	306	Dec. 21	......do	3	0	....do	12	0	0
Barometer, 30.119; thermometer, 38; relative humidity, 89; wind 24 miles an hour.	307	Dec. 22	......do	2	8	....do	12	0	0
	308	Dec. 22	......do	2	8	....do	12	0	0
	309	Dec. 22	......do	2	8	....do	12	0	0
	310	Dec. 22	......do	2	8	....do	12	0	0
	311	Dec. 22	......do	2	8	....do	12	0	0
	312	Dec. 22	......do	2	8	....do	12	0	0
	313	Dec. 22	......do	2	8	....do	12	0	0
	314	Dec. 22	......do	2	8	....do	12	0	0
	315	Dec. 22	......do	2	8	....do	12	0	0
	316	Dec. 22	......do	2	8	....do	12	0	0
	317	Dec. 22	......do	2	8	....do	12	0	0
	318	Dec. 22	......do	2	8	....do	12	0	0
	319	Dec. 22	......do	2	8	....do	12	0	0

GUN MOUNTED ON IRON CARRIAGE

Barometer, 30.215; thermometer, 36; relative humidity, 71; wind 5 miles an hour.	320	Dec. 28	Du Pont's I. K. B. Density, 1,725; granulation, 2,200.	3	0	Hotchkiss cored shot.	12	0	0
	321	Dec. 28	......do	3	0	....do	12	0	0
	322	Dec. 28	......do	3	0	....do	12	0	0
	323	Dec. 28	......do	3	0	....do	12	0	0
	324	Dec. 28	......do	3	0	....do	12	0	0
	325	Dec. 28	......do	3	0	....do	12	0	0
	326	Dec. 28	......do	3	0	....do	12	0	0
	327	Dec. 28	......do	3	0	....do	12	0	0
	328	Dec. 28	......do	3	0	....do	12	0	0
	329	Dec. 28	......do	3	0	....do	12	0	0
	330	Dec. 28	......do	3	0	....do	12	0	0
	331	Dec. 28	......do	3	0	....do	12	0	0
	332	Dec. 28	......do	3	0	.. do	12	0	0
	333	Dec. 28	......do	3	0	....do	12	0	0
	334	Dec. 28	..... do	3	0	....do	12	0	0
	335	Dec. 28	......do	3	0	... do	12	0	0
	336	Dec. 28	......do	3	0	....do	12	0	0

774, chambered, at Sandy Hook, N. J., &c.—Continued.

Instrumental velocity 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.			
Feet.	*Feet.*					
1, 523	7. 00	From left to right.	Gun on plank road.	Fired into sand butt.	Spring brake.	
1, 527	7. 83					
1, 528	7. 00					After round 306 gun washed out, examined, and star-gauged.
....	12. 00				Same brake as used on iron carriage adjusted to fit wooden carriage.	Before round 307 gun dismounted from iron carriage and mounted on wooden carriage having new stock furnished from Watervliet arsenal and finished and fitted at Sandy Hook.
....	11. 00					
....	10. 00					
....	10. 00					At 307th round, spring-brake connecting axle with wheel on left side of carriage was released by firing, freeing itself from the wheel and turning the carriage partly around to the right.
....	10. 00					
....	10. 00					
....	10. 00					At 310th round, shoe of brake over tire of wheel slipped, but did not entirely release itself.
....	10. 00					
....	10. 00					
....	4. 00		Gun in sand.			
....	4. 00					
....	4. 00					
....	4. 00					Both carriages, iron and wooden, in good condition after firing.

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....	7. 00	From rear.	Gun on plank road.	Fired into sand butt.	Solid breech block used. Spring brake connecting axle with tre of wheel by means of a shoe used to take up part of recoil.		Right hand cap square bent slighly at round 320, and continued to bend more at each succeeding round until at round 340 it had opened about one fourth of an inch. Its pin also bent.
....	7. 00						
....	7. 00						
....	7. 00						
....	7. 00						
....	8. 00						
....	8. 00						
....	8. 00						
....	8. 00						
....	8. 00						
....	8. 00						
....	8. 25					Trail handspike broke in two.	
....	8. 00						
....	8. 25						
....	8. 25						
....	8. 00						
....	8. 00						

Record of firing with 3.20-inch breech-loading rifle No.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.
			Kind.	Weight.	Kind.	Weight.	
		1882.		*Lbs.*		*Lbs.*	°
Barometer, 30.215; thermometer, 36; relative humidity, 71; wind, 5 miles an hour.	337	Dec. 28	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Hotchkiss (cored shot.)	12	0
	338	Dec. 28	......do	3	....do	12	0
	339	Dec. 28	......do	3	....do	12	0
	340	Dec. 28	......do	3	....do	12	0
		1883.					
P. M.—Barometer, 30.432; thermometer, 27; relative humidity, 72; wind, 13 miles an hour.	341	Jan. 26	......do	3	Hotchkiss (new), 1 copper band.	12	0
	342	Jan. 26	......do	3	....do	12	0
	343	Jan. 26	......do	3	....do	12	0
	344	Jan. 26	......do	3	....do	12	0
	345	Jan. 26	......do	3	....do	12	0
	346	Jan. 26	......do	3	....do	12	0
	347	Jan. 26	......do	3	....do	12	0
	348	Jan. 26	......do	3	....do	12	0
	349	Jan. 26	......do	3	....do	12	0
	350	Jan. 26	......do	3	....do	12	0
	351	Jan. 26	......do	3	....do	12	0
	352	Jan. 26	......do	3	....do	12	0
	353	Jan. 26	......do	3	....do	12	0
	354	Jan. 26	......do	3	....do	12	0
	355	Jan. 26	......do	3	....do	12	0
	356	Jan. 26	......do	3	....do	12	0
	357	Jan. 26	......do	3	....do	12	0
	358	Jan. 26	......do	3	....do	12	0
	359	Jan. 26	......do	3	....do	12	0
	360	Jan. 26	......do	3	....do	12	0
	361	Jan. 26	......do	3	....do	12	0
	362	Jan. 26	......do	3	....do	12	0
	363	Jan. 26	......do	3	....do	12	0
	364	Jan. 26	......do	3	....do	12	0
	365	Jan. 26	......do	3	....do	12	0
	366	Jan. 26	......do	3	....do	12	0
	367	Jan. 26	......do	3	....do	12	0
	368	Jan. 26	......do	3	....do	12	0
	369	Jan. 26	......do	3	....do	12	0
	370	Jan. 26	......do	3	....do	12	0

774, *chambered, at Sandy Hook, N. J., &c.*—Continued.

Pressure per square inch of bore.	Instrumental velocity 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Lbs.	*Feet.*	*Feet.*		
....	....	8.00	From rear and left.	Fired into sand butt to try carriage. Gun on plank road.
....	....	8.00		See remarks on previous page (December 28, 1882).
....	....	8.00		
....	....	8.00		
21,500	1,518	10.00		Before 341st round new cap squares put on carriage, one-half inch thicker than old ones.
....	....	8.00		
....	....	8.50		
....	....	9.00		
....	....	9.00		
....	....	10.00		
....	....	9.00		
....	....	9.00		
....	....	8.50		
....	....	9.00		
24,000	1,526	8.00		
....	....	8.00		
....	....	8.00		
....	....	8.00		
....	....	8.00		
....	....	8.00		
....	....	8.00		
....	....	8.00		
....	....	8.00		
....	....	8.00		After 360th round gun washed out, examined, and star-gauged.
23,000	1,520	8.00		
....	....	8.00		
....	....	8.00		
....	....	8.00		
....	....	8.50		
....	....	8.00		
....	....	8.00		
....	....	8.00		
....	....	8.00		
....	....	8.00		

Record of firing with 3.20-inch breech-loading rifle No.

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.
		1883.		*Lbs.*		*Lbs.*	°
P. M.—Barometer, 30.432; thermometer, 27; relative humidity, 72; wind, 13 miles an hour.	371	Jan. 26	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Hotchkiss (new), 1 copper band.	12	0
	372	Jan. 26	......do	3	....do	12	0
	373	Jan. 26	......do	3	....do	12	0
	374	Jan. 26	......do	3	....do	12	0
	375	Jan. 26	......do	3	....do	12	0
	376	Jan. 26	......do	3	....do	12	0
	377	Jan. 26	......do	3	....do	12	0
	378	Jan. 26	......do	3	....do	12	0
	379	Jan. 26	......do	3	....do	12	0
	380	Jan. 26	......do	3	....do	12	0
A. M.—Barometer, 30.239; thermometer, 37; relative humidity, 88; wind, 13 miles an hour.	381	Jan. 27	......do	3	....do	12	−¼
	382	Jan. 27	......do	3	....do	12	−¼
	383	Jan. 27	......do	3	....do	12	−¼
	384	Jan. 27	......do	3	....do	12	−¼
	385	Jan. 27	......do	3	....do	12	−¼
	386	Jan. 27	......do	3	....do	12	−¼
	387	Jan. 27	......do	3	....do	12	−¼
	388	Jan. 27	......do	3	....do	12	−¼
	389	Jan. 27	......do	3	....do	12	−¼
	390	Jan. 27	......do	3	....do	12	−¼
	391	Jan. 27	......do	3	....do	12	−¼
	392	Jan. 27	......do	3	....do	12	−¼
	393	Jan. 27	......do	3	....do	12	−¼
	394	Jan. 27	......do	3	....do	12	−¼
	395	Jan. 27	......do	3	....do	12	−¼
	396	Jan. 27	......do	3	....do	12	−¼
	397	Jan. 27	......do	3	....do	12	−¼
	398	Jan. 27	......do	3	....do	12	−¼
	399	Jan. 27	......do	3	....do	12	−¼
	400	Jan. 27	......do	3	....do	12	−¼

774, *chambered, at Sandy Hook, N. J., &c.*—Continued.

Pressure per square inch of bore.	Instrumental velocity 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Lbs.	*Feet.*	*Feet.*		
23, 000	1, 524	8. 00	From rear and left.	Fired into sand butt to try carriage. Gun on plank road.
....	....	8. 00		
....	....	8. 00		
....	....	8. 00		
....	....	8. 00		
....	....	8. 00		
....	....	8. 00		
....	....	8. 00		
....	....	8. 00		
....	....	8. 00		After 380th round gun washed out, examined, and star-gauged.
23, 500	1, 522	8. 00	From front and right.	
....	....	8. 00		
....	....	8. 00		
....	....	8. 50		
....	....	8. 00		
....	....	8. 00		
....	....	8. 50		
....	....	8. 50		
....	....	8. 50		
....	....	8. 50		
23, 000	1, 523	8. 50		
....	....	8. 00		
....	....	8. 50		
......	....	8. 50		
......	....	8. 50		
....	....	8. 50		
....	....	8. 50		
....	....	8. 50		
....	....	8. 00		
....	....	8. 00		After 400th round gun washed out, examined, and star-gauged

Record of firing with 3.20-inch breech-loading rifle No.

	Number of fire.	Time.	Powder.		Projectile.		
			Kind.	Weight.	Kind.	Weight.	Elevation.
		1883.		*Lbs.*		*Lbs.*	
A. M.—Barometer, 30.177; thermometer, 40; relative humidity, 73; wind, 12 miles an hour.	401	Jan. 27	Du Pont's I. K. D. Density, 1.725; granulation, 2,200.	3	Hotchkiss (new), 1 copper band.	12	−¼
	402	Jan. 27	......do	3	....do	12	−¼
	403	Jan. 27	......do	3	....do	12	−¼
	404	Jan. 27	......do	3	....do	12	−¼
	405	Jan. 27	......do	3	....do	12	−¼
	406	Jan. 27	......do	3	....do	12	−¼
	407	Jan. 27	......do	3	....do	12	−¼
	408	Jan. 27	......do	3	....do	12	−¼
	409	Jan. 27	......do	3	....do	12	−¼
	410	Jan. 27	......do	3	....do	12	−¼
	411	Jan. 27	......do	3	....do	12	−¼
	412	Jan. 27	......do	3	....do	12	−¼
	413	Jan. 27	......do	3	....do	12	−¼
	414	Jan. 27	......do	3	....do	12	−¼
	415	Jan. 27	......do	3	....do	12	−¼
	416	Jan. 27	......do	3	....do	12	−¼
	417	Jan. 27	......do	3	....do	12	−¼
	418	Jan. 27	......do	3	....do	12	−¼
	419	Jan. 27	......do	3	....do	12	−¼
	420	Jan. 27	......do	3	....do	12	−¼
	421	Jan. 27	......do	3	....do	12	−¼
	422	Jan. 27	......do	3	....do	12	−¼
	423	Jan. 27	......do	3	....do	12	−¼
	424	Jan. 27	......do	3	....do	12	−¼
	425	Jan. 27	......do	3	....do	12	−¼
	426	Jan. 27	......do	3	....do	12	−¼
	427	Jan. 27	......do	3	....do	12	−¼
	428	Jan. 27	......do	3	....do	12	−¼
	429	Jan. 27	......do	3	....do	12	−¼
	430	Jan. 27	......do	3	....do	12	−¼

774, chambered, at Sandy Hook, N. J., &c.—Continued.

Pressure per square inch of bore.	Instrumental velocity 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
Lbs.	*Feet.*	*Feet.*		*Feet.*		
26, 000	1, 516	8. 00	From front and right.	......	Fired into sand butt to try carriage. Gun on plank road.	
......	......	8. 00		......		
......	......	8. 00		......		
......	......	8. 00		......		
......	......	8. 00		......		
......	......	8. 00		......		
......	......	8. 00		......		
......	......	8. 00		......		
......	......	8. 00		......		
......	......	8. 00		....		
25, 000	1, 524	7. 50		0. 83		
......	......	8. 50		1. 00		
......	......	8. 00		0. 92		
......	......	8. 00		0. 17		
......	......	8. 00		0. 83		After 420th round gun washed out, examined, and star gauged.
......	......	8. 00		0. 83		
......	......	8. 00		0. 92		
......	......	7. 50		0. 83		
......	......	8. 00		0. 83		
......	......	8. 00		0. 67		
25, 500	1, 527	8. 00		0. 08		
......	......	8. 00		0. 83		
......	......	8. 00		0. 67		
......	......	8. 50		0. 83		
......	......	8. 00		0. 67		
......	......	8. 00		0. 67		
......	......	8. 00		0. 42		
......	......	8. 00		0. 42		
......	......	8. 00		0. 42		
......	......	8. 00		0. 33		

Record of firing with 3.20-inch breech-loading rifle No.

	Number of fire.	Time.	Powder.		Projectile.		
			Kind.	Weight.	Kind.	Weight.	Elevation.
		1882.		*Lbs.*		*Lbs.*	°
A. M.—Barometer, 30.177; thermometer, 40; relative humidity, 73; wind, 12 miles an hour.	431	Jan. 27	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Hotchkiss (new), 1 copper band.	12	−¼
	432	Jan. 27	......do	3	....do	12	−¼
	433	Jan. 27	......do	3	....do	12	−¼
	434	Jan. 27	......do	3	....do	12	−¼
	435	Jan. 27	......do	3	....do	12	−¼
	436	Jan. 27	......do	3	....do	12	−¼
	437	Jan. 27	......do	3	....do	12	−¼
	438	Jan. 27	......do	3	....do	12	−¼
	439	Jan. 27	......do	3	....do	12	−¼
	440	Jan. 27	......do	3	....do	12	−¼
At beginning of firing.—barometer, 29.863; thermometer, 42; relative humidity, 65; wind, 11 miles an hour.	441	Feb. 7	Du Pont's I. K. B. Density, 1.725; granulation, 2.200.	3	Hotchkiss (rebanded, 1 copper band.	12	−¼
	442	Feb. 7	......do	3	....do	12	−¼
	443	Feb. 7	......do	3	....do	12	−¼
	444	Feb. 7	......do	3	....do	12	−¼
	445	Feb. 7	......do	3	....do	12	−¼
	446	Feb. 7	......do	3	....do	12	−¼
	447	Feb. 7	......do	3	....do	12	−¼
	448	Feb. 7	......do	3	....do	12	−¼
	449	Feb. 7	......do	3	....do	12	−¼
	450	Feb. 7	......do	3	....do	12	−¼

774, chambered, at Sandy Hook, N. J., &c.—Continued.

Pressure per square inch of bore.	Instrumental velocity 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Lbs.	*Feet.*	*Feet.*		*Feet.*	
24, 000	1, 516	8. 00	From front and right.	0. 33	Fired into sand butt to try carriage. Gun on plank road.
....	....	8. 00		0. 67	
....	....	8. 00		0. 83	
....	....	8. 00		0. 92	
....	....	8. 50		0. 67	
....	....	8 00		0. 67	
....	....	8. 50		0. 83	
......	....	8. 50		0. 58	
....	....	8. 00		0. 83	
....	.....	8. 00		0. 75	After 440th round gun washed out, examined, and star gauged.

NOTES.—Gun mounted on carriage modified by Lieut. Col. A. R. Buffington.

Spring brake connecting axle with tire of wheel by means of a shoe used to take up part of the recoil.

During all firing in this report (January 26 and 27) elevating screw replaced by wooden block at breech of gun.

Carriage worked well throughout the firing.

Spring brakes taken apart and spring examined; no particular evidence of wearing noticed; one spring slightly out of line; both springs subjected to a pressure of 1,450 pounds, which brought the coils of the spring close together. Upon pressure being released springs did not entirely recover their previous length, one being shortened ¼ of an inch and the other 1/16.

During the star-gauging after 440th round, a flaw was detected in the bore. Attention being called to it, impressions were taken, which showed four cavities in the upper right-hand side of bore. First two were 10⅛ and 11⅛ inches from muzzle; the other two, the deepest one, 29⅛″ from the muzzle and the other one in its immediate neighborhood. The deepest one on being roughly measured shows a cavity of 1⅛″ in depth.

Pressure per square inch of bore.	Instrumental velocity 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
27, 000	1, 512	12. 00	From rear and right.	......	Fired into sand butt to try carriage.
....	....	12. 00		......	
....	....	10. 50		......	
....	....	12. 00		......	
....	....	12. 75		0. 75	
....	....	12. 00		......	
....	....	12. 50		0. 50	
....	....	12. 00		......	
......	....	12. 50		0. 25	
....	....	13. 00		0. 50	

Record of firing with 3.20-inch breech-loading rifle No.

	Number of fire.	Time.	Powder.		Projectile.		
			Kind.	Weight.	Kind.	Weight.	Elevation.
				Lbs.		*Lbs.*	°
At end of firing: Barometer, 29.982; thermometer, 42; relative humidity, 65; wind, 28 miles an hour.	451	Feb. 7	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Hotchkiss rebanded, 1 copper band.	12	
	452	Feb. 7	......do	3	....do	12	
	453	Feb. 7	......do	3	....do	12	
	454	Feb. 7	......do	3	....do	12	
	455	Feb. 7	......do	3	....do	12	
	456	Feb. 7	......do	3	....do	12	
	457	Feb. 7	......do	3	....do	12	
	458	Feb. 7	......do	3	....do	12	
	459	Feb. 7	......do	3	....do	12	
	460	Feb. 7	......do	3	....do	12	
	461	Feb. 7	......do	3	....do	12	
	462	Feb. 7	......do	3	....do	12	
	463	Feb. 7	......do	3	....do	12	
	464	Feb. 7	......do	3	....do	12	
	465	Feb. 7	......do	3	....do	12	
	466	Feb. 7	......do	3	....do	12	
	467	Feb. 7	......do	3	....do	12	
	468	Feb. 7	......do	3	....do	12	
	469	Feb. 7	......do	3	....do	12	
	470	Feb. 7	......do	3	....do	12	
	471	Feb. 7	......do	3	....do	12	
	472	Feb. 7	......do	3	....do	12	
	473	Feb. 7	......do	3	....do	12	
	474	Feb. 7	......do	3	....do	12	
	475	Feb. 7	......do	3	....do	12	
	476	Feb. 7	......do	3	....do	12	
	477	Feb. 7	......do	3	....do	12	
	478	Feb. 7	......do	3	....do	12	
	479	Feb. 7	......do	3	....do	12	
	480	Feb. 7	......do	3	....do	12	

774, chambered, at Sandy Hook, N. J., &c.—Continued.

Pressure per square inch of bore.	Instrumental velocity, 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Lbs.	*Feet.*	*Feet.*		*Feet.*		
26, 000	1, 524	10. 50	From rear and right.	0. 50	Fired into sand butt to try carriage.	Round 451, escape of gas all around check.
		10. 00	do	0. 50		
		10. 50	do	0. 50		
		10. 50	do	0. 50		
		10. 50	do	0. 50		
		10. 25	do	0. 50		
		10. 50	do	0. 50		
		10. 50	do	0. 25		
		10. 50	do	0. 25		
		10. 50	do	0. 50		After round 460, gun washed out, examined, and star gauged.
24, 500	1, 520	10. 50	do	0. 75		
		10. 00	do	0. 25		
		10. 00	do	0. 25		
		10. 50	do	0. 50		
		10. 25	do	0. 50		
		10. 25	do	0. 25		
		10. 25	do	0. 25		
		10. 50	do	0. 50		
		10. 00	do	0. 50		
		9. 50	do	0. 50		
22, 500	1, 501	10. 00	do	0. 75		Round 471, escape of gas all around check.
25, 000	1, 521	9. 00	do	0. 50		
		9. 00	do	0. 67		
		9. 00	do	0. 75		
		9. 00	do	0. 75		
		10. 00	do	0. 25		
		10. 00	do	0. 50		
		9. 00	do	0. 25		
		9. 00	do	0. 83		
		9. 00	do	0. 25		After 480th round gun washed out, examined, and star gauged.

Record of firing with 3.20-inch breech-loading rifle No

	Number of fire.	Time.	Powder.		Projectile.		Elevation.
			Kind.	Weight.	Kind.	Weight.	
At beginning of firing: Barometer, 30.223; thermometer, 39; relative humidity, 76; wind, 10 miles an hour.	481	1883. Feb. 8	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	*Lbs.* 3	Hotchkiss, rebanded, 1 copper band.	*Lbs.* 12	° −1
	482	Feb. 8	......do	3	....do	12	−1
	483	Feb. 8	......do	3	....do	12	−1
	484	Feb. 8	......do	3	....do	12	−1
	485	Feb. 8	......do	3	....do	12	−1
	486	Feb. 8	......do	3	....do	12	−1
	487	Feb. 8	......do	3	....do	12	−1
	488	Feb. 8	......do	3	....do	12	−1
	489	Feb. 8	......do	3	....do	12	−1
	490	Feb. 8	......do	3	....do	12	−1
	491	Feb. 8	......do	3	....do	12	−1
	492	Feb. 8	......do	3	....do	12	−1
	493	Feb. 8	......do	3	....do	12	−1
	494	Feb. 8	......do	3	....do	12	−1
	495	Feb. 8	......do	3	....do	12	−1
	496	Feb. 8	......do	3	....do	12	−1
	497	Feb. 8	......do	3	....do	12	−1
	498	Feb. 8	......do	3	....do	12	−1
	499	Feb. 8	......do	3	....do	12	−1
	500	Feb. 8	......do	3	....do	12	−1
	501	Feb. 8	......do	3	....do	12	−1
	502	Feb. 8	......do	3	....do	12	−1
	503	Feb. 8	......do	3	....do	12	−1
	504	Feb. 8	......do	3	....do	12	−1
	505	Feb. 8	......do	3	....do	12	−1
	506	Feb. 8	......do	3	....do	12	−1
	507	Feb. 8	......do	3	....do	12	−1
	508	Feb. 8	......do	3	....do	12	−1
	509	Feb. 8	......do	3	....do	12	−1
	510	Feb. 8	......do	3	....do	12	−1

774, *chambered, at Sandy Hook, N. J., &c.*—Continued.

Pressure per square inch of bore.	Instrumental velocity, 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Lbs.	*Feet.*	*Feet.*		*Feet.*	
25, 500	1, 514	8. 25	From rear and right.	0. 50	Fired into sand butt to try carriage.
......	....	8. 25	......do	. 50	
......	....	8. 00	......do	. 25	
......	....	8. 00	......do	. 25	
......	....	8. 00	......do	. 25	
......	....	8. 00	......do	. 25	
......	....	9. 00	..... do	. 50	
......	....	8. 00	......do	. 25	
......	....	8. 50	......do	. 25	
......	....	9. 00	......do	. 50	
24, 000	1, 518	8. 00	.. .. do	. 50	
......	....	9. 00	......do	. 50	
......	....	9. 00	......do	. 50	
......	....	9. 50	......do	. 50	
......	....	9. 50	......do	. 50	
......	....	8. 00	......do	. 50	
......	....	9. 00	......do	. 50	
......	....	9. 00	......do	. 50	
......	....	9. 00	......do	. 50	
......	....	9. 00	..... do	. 50	After 500th round gun washed out, examined, star-gauged, and impressions of the bore taken.
24, 000	1, 515	9. 00	......do	. 75	
......	....	8. 00	......do	. 25	
......	....	8. 00	......do	. 50	
......	....	8. 50	......do	. 25	
......	....	8. 00	......do	. 25	
......	....	8. 00	..... do	. 50	
......	....	8. 00	......do	. 50	
......	....	8. 00	......do	. 50	
......	....	8. 00	......do	. 25	
......	....	8. 50	......do	. 50	

Record of firing with 3.20-*inch* ***breech-loading*** *rifle No.*

	Number of fire.	Time.	Powder.		Projectile.		
			Kind.	Weight.	Kind.	Weight.	Elevation.
		1883.		*Lbs.*		*Lbs.*	°
At end of firing: Barometer, 30.235; thermometer, 31; relative humidity, 78; wind, 20 miles an hour.	511	Feb. 8	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	**Hotchkiss, rebanded, 1 copper band**	12	−¼
	512	Feb. 8	......do	3	....do	12	−¼
	513	Feb. 8	......do	3	....do	12	−¼
	514	Feb. 8	......do	3	....do	12	−¼
	515	Feb. 8	......do	3	....do	12	−¼
	516	Feb. 8	......do	3	....do	12	−¼
	517	Feb. 8	......do	3	....do	12	−¼
	518	Feb. 8	......do	3	....do	12	−¼
	519	Feb. 8	......do	3	....do	12	−¼
	520	Feb. 8	......do	3	....do	12	−¼
	521	Feb. 8	......do	3	....do	12	−¼
	522	Feb. 8	......do	3	....do	12	−¼
	523	Feb. 8	......do	3	....do	12	−¼
	524	Feb. 8	......do	3	....do	12	−¼
	525	Feb. 8	......do	3	....do	12	−¼
	526	Feb. 8	......do	3	....do	12	−¼
	527	Feb. 8	......do	3	....do	12	−¼
	528	Feb. 8	......do	3	....do	12	−¼
	529	Feb. 8	......do	3	....do	12	−¼
	530	Feb. 8	......do	3	....do	12	−¼
	531	Feb. 8	......do	3	....do	12	−¼
	532	Feb 8	......do	3	....do	12	−¼
	533	Feb. 8	......do	3	....do	12	−¼
	534	Feb. 8	......do	3	....do	12	−¼
	535	Feb. 8	......do	3	....do	12	−¼
	536	Feb. 8	......do	3	....do	12	−¼
	537	Feb. 8	......do	3	....do	12	−¼
	538	Feb. 8	......do	3	....do	12	−¼
	539	Feb. 8	......do	3	....do	12	−¼
	540	Feb. 8	......do	3	....do	12	−¼
						12	−¼

774, chambered, at Sandy Hook, N. J., &c.—Continued.

Pressure per square inch of bore.	Instrumental velocity 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Lbs.	*Feet.*	*Feet.*		*Feet.*		
24, 000	1, 519	8. 00	From rear and right	0. 25	Fired into sand butt to try carriage.	
......	....	8. 00	......do	.50		
......	....	8. 50	......do	.50		
......	....	8. 50	..... do	.50		
......	....	8. 50	......do	.75		
......	....	8. 50	......do	.50		
......	....	8. 00	......do	.25		
......	....	8. 50	......do	.50		
......	....	8. 50	......do	.50		
......	....	8. 50	......do	.50		
24, 500	1, 520	8. 50	......do	.75		After 520th round gun washed out, examined, star-gauged, and impressions of bore taken.
......	....	8. 00	......do	.50		
......	....	8. 00	......do	.50		
......	....	8. 00	......do	.25		
......	....	8. 00	......do	.50		
......	....	8. 00	......do	.50		
......	....	8. 50	......do	.67		
......	....	8. 50	......do	.75		
......	....	8. 50	......do	.75		
......	....	8. 50	......do	.75		
23, 500	1, 522	8. 50	......do	.75		Round 530, bolt fastening trail socket to trail broke (right side).
......	....	8. 00	......do	.50		
......	....	9. 00	......do	.75		
......	....	8. 50	..... do	.25		
......	....	8. 00	......do	.50		
......	....	8. 00	......do	.50		
......	....	8. 50	......do	.75		
......	....	8. 50	......do	.50		
......	....	8. 50	......do	.75		
......	....	8. 50	......do	.75		After 540th round gun washed out, examined, and star-gauged.

Record of firing with 3.20-inch breech-loading rifle No.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.
			Kind.	Weight.	Kind.	Weight.	
		1883.		*Lbs.*		*Lbs.*	°
At beginning of firing: Barometer, 30.274; thermometer, 30; relative humidity, 88; wind, 6 miles an hour.	541	Feb. 14	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Hotchkiss, rebanded, 1 copper band.	12	−¼
	542	Feb. 14	......do	3	....do	12	−¼
	543	Feb. 14	......do	3	....do	12	−¼
	544	Feb. 14	......do	3	....do	12	−¼
	545	Feb. 14	......do	3	....do	12	−¼
	546	Feb. 14	......do	3	....do	12	−¼
	547	Feb. 14	......do	3	....do	12	−¼
	548	Feb. 14	......do	3	....do	12	−¼
	549	Feb. 14	......do	3	....do	12	−¼
	550	Feb. 14	......do	3	....do	12	−¼
	551	Feb. 14	......do	3	....do	12	−¼
	552	Feb. 14	......do	3	....do	12	−¼
	553	Feb. 14	......do	3	....do	12	−¼
	554	Feb. 14	......do	3	....do	12	−¼
	555	Feb. 14	......do	3	....do	12	−¼
	556	Feb. 14	......do	3	....do	12	−¼
	557	Feb. 14	......do	3	....do	12	−¼
	558	Feb. 14	......do	3	....do	12	−¼
	559	Feb. 14	......do	3	....do	12	−¼
	560	Feb. 14	......do	3	....do	12	−¼
	561	Feb. 14	......do	3	....do	12	−¼
	562	Feb. 14	......do	3	....do	12	−¼
	563	Feb. 14	......do	3	....do	12	−¼
	564	Feb. 14	......do	3	....do	12	−¼
	565	Feb. 14	......do	3	....do	12	−¼
	566	Feb. 14	......do	3	....do	12	−¼
	567	Feb. 14	......do	3	....do	12	−¼
	568	Feb. 14	......do	3	....do	12	−¼
	569	Feb. 14	......do	3	....do	12	−¼
	570	Feb. 14	......do	3	....do	12	−¼

774, *chambered, at Sandy Hook, N. J., &c.*—Continued.

Pressure per square inch of bore.	Instrumental velocity 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Lbs.	*Feet.*	*Feet.*		*Feet.*	
27, 500	1, 527	7. 50	From right to left	0. 50	Fired into sand butt to try carriage.
......	......	9. 00	do	.25	
......	......	10. 25	do	.25	
......	......	10. 00	do	.25	
......	......	9. 00	do	.50	
......	......	9. 75	do	.50	
......	......	8. 75	do	.50	
......	......	8. 50	do	.50	
......	......	8. 25	do	.25	
......	......	8. 25	do	.25	
24, 500	1, 512	8. 00	do	.25	
......	......	9. 17	do	.33	
......	......	9. 25	do	.08	
......	......	9. 25	do	.17	
......	......	9. 50	do	.25	
......	......	9. 00	do	.67	
......	......	10. 25	do	.50	
......	......	10. 67	do	.67	Gas check shows gas cuts in four different places across first cannelure and partly into second, after being examined after 560th round, and were developed during last 10 rounds.
......	......	10. 50	do	.67	
......	......	10. 17	do	.67	
26, 500	1, 522	13. 00	do	.75	
......	......	10. 00	do	.50	
......	......	9. 00	do	.25	After 560th round gun washed out, examined, and star-gauged.
......	......	10. 50	do	.75	
......	......	11. 00	do	.83	
......	......	11. 50	do	1. 00	
......	......	11. 00	do	.83	
......	......	11. 17	do	1. 00	
......	......	11. 50	do	1. 00	
......	......	12. 00	do	.00	Gas check examined, and shows no material change in last 10 rounds.

Record of firing with 3.20-*inch breech-loading rifle* No.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.
			Kind.	Weight.	Kind.	Weight.	
		1883.		*Lbs.*		*Lbs.*	°
At end of firing: Barometer, 30.064; thermometer, 36; relative humidity, 100; wind, 14 miles an hour.	571	Feb. 14	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Hotchkiss, rebanded, 1 copper band.	12	−¼
	572	Feb. 14	......do	3	....do	12	−¼
	573	Feb. 14	......do	3	....do	12	−¼
	574	Feb. 14	......do	3	....do	12	−¼
	575	Feb. 14	......do	3	....do	12	−¼
	576	Feb. 14	......do	3	....do	12	−¼
	577	Feb. 14	......do	3	....do	12	−¼
	578	Feb. 14	......do	3	....do	12	−¼
	579	Feb. 14	......do	3	....do	12	−¼
	580	Feb. 14	......do	3	....do	12	−¼
A. M.—Barometer, 30.287; thermometer, 30; relative humidity, 78; wind, 25 miles an hour.	581	Feb. 23	......do	3	....do	12	−¼
	582	Feb. 23	......do	3	....do	12	−¼
	583	Feb. 23	......do	3	....do	12	−¼
	584	Feb. 23	......do	3	....do	12	−¼
	585	Feb. 23	......do	3	....do	12	−¼
	586	Feb. 23	......do	3	....do	12	−¼
	587	Feb. 23	......do	3	....do	12	−¼
	588	Feb. 23	......do	3	....do	12	−¼
	589	Feb. 23	......do	3	....do	12	−¼
	590	Feb. 23	......do	3	....do	12	−¼
	591	Feb. 23	......do	3	....do	12	−¼
	592	Feb. 23	......do	3	....do	12	−¼
	593	Feb. 23	......do	3	....do	12	−¼
	594	Feb. 23	......do	3	....do	12	−¼
	595	Feb. 23	......do	3	....do	12	−¼
	596	Feb. 28	......do	3	....do	12	−¼
	597	Feb. 23	......do	3	....do	12	−¼
	598	Feb. 23	......do	3	....do	12	−¼
	599	Feb. 23	......do	3	....do	12	−¼
	600	Feb. 23	......do	3	....do	12	−¼

774, *chambered, at Sandy Hook, N. J., &c.*—Continued.

Pressure per square inch of bore.	Instrumental velocity, 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Lbs.	*Feet.*	*Feet.*		*Feet.*		
23, 500	1, 512	11. 50	From left to right ..	1. 00	Fired into sand butt to try carriage.	After 580th round, gun washed out, examined, star-gauged, and impressions of bore taken; gas cuts deepened slightly, but not apparently lengthened. Since last firing face of gas check ground down, so as to take out gas cuts and new obturator plate put in.
....	....	13. 50	......do	1. 00		
......	....	14. 00	......do	. 50		
....	....	14. 00	......do	. 25		
....	....	14. 00	..... do	. 25		
....	....	17. 00	......do	. 08		
....	....	17. 00	......do	. 50		
....	....	15. 00	..... do	. 00		
....	....	15. 00	......do	. 83		
....	....	13. 00	......do	. 50		
22, 000	1, 510	7. 50	From rear	. 25		
....	....	7. 50	.....do	. 25		
....	....	8. 25	......do	. 50		
....	....	8. 00	..... do	. 50		
....	....	8. 00	..... do	. 50		After 600th round, gun washed out, examined, and star-gauged.
....	....	8. 00	......do	. 25		
....	....	8. 00	......do	. 50		
....	....	8 00	......do	. 50		
....	....	8. 25	......do	. 50		
....	....	8. 25	......do	. 50		
24, 500	1, 524	7. 50	..... do	. 25		
....	....	8. 00	......do	. 50		
....	....	8. 00	.. .. do	. 50		
......	....	8. 00	......do	. 50		
....	....	8. 00	..... do	. 50		
..... .	....	8. 00	......do	. 50		
....	....	8. 00	......do	. 75		
......	....	8. 25	......do	. 50		
....	....	8. 00	......do	. 50		
....	....	7. 75	..... do	. 25		

Record of firing with 3.20-inch breech-loading rifle No.

	Number of fire.	Time.	Powder.		Projectile.		
			Kind.	Weight.	Kind.	Weight.	Elevation.
		1883.		*Lbs.*		*Lbs.*	°
A. M.—Barometer, 30.287; thermometer, 30; relative humidity, 78; wind, 25 miles an hour.	601	Feb. 23	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Hotchkiss rebanded, 1 copper band.	12	−¼
	602	Feb. 23	do	3	do	12	−¼
	603	Feb. 23	do	3	do	12	−¼
	604	Feb. 23	do	3	do	12	−¼
	605	Feb. 23	do	3	do	12	−¼
	606	Feb. 23	do	3	do	12	−¼
	607	Feb. 23	do	3	do	12	−¼
	608	Feb. 23	do	3	do	12	−¼
	609	Feb. 23	do	3	do	12	−¼
	610	Feb. 23	do	3	do	12	−¼
	611	Feb. 23	do	3	do	12	−¼
	612	Feb. 23	do	3	do	12	−¼
	613	Feb. 23	do	3	do	12	−¼
	614	Feb. 23	do	3	do	12	−¼
	615	Feb. 23	do	3	do	12	−¼
	616	Feb. 23	do	3	do	12	−¼
	617	Feb. 23	do	3	do	12	−¼
	618	Feb. 23	do	3	do	12	−¼
	619	Feb. 23	do	3	do	12	−¼
	620	Feb. 23	do	3	do	12	−¼
A. M.—Barometer, 30.348; thermometer, 30; relative humidity, 78; wind, 24 miles an hour.	621	Feb. 23	do	3	do	12	−¼
	622	Feb. 23	do	3	do	12	−¼
	623	Feb. 23	do	3	do	12	−¼
	624	Feb. 23	do	3	do	12	−¼
	625	Feb. 23	do	3	do	12	−¼
	626	Feb. 23	do	3	do	12	−¼
	627	Feb. 23	do	3	do	12	−¼
	628	Feb. 23	do	3	do	12	−¼
	629	Feb. 23	do	3	do	12	−¼
	630	Feb. 23	do	3	do	12	−¼

774, chambered, at Sandy Hook, N. J., &c.—Continued.

Pressure per square inch of bore.	Instrumental velocity, 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
Lbs.	*Feet.*	*Feet.*		*Feet.*		
24,000	1,493	7.50	From rear	0.25	Fired into sand butt to try carriage.	
		8.25	do	.50		
		8.25	do	.50		
		8.50	do	.75		
		8.00	do	.50		
		8.00	do	.50		
		8.50	do	.75		
		8.50	do	.75		
		8.50	do	.25		
		8.25	do	.50		
22,000	1,507	7.50	do	.08		
		8.00	do	.25		
		8.25	do	.50		
		8.25	do	.50		
		8.00	do	.50		
		8.00	do	.33		
		8.00	do	.50		
		8.25	do	.50		
		8.25	do	.33		
		8.25	do	.75		After 620th round, gun washed out, examined, and star-gauged.
24,500	1,511	7.75	do	.00		
		8.00	do	.25		
		8.00	do	.50		
		8.25	do	.83		
		8.00	do	.25		
		8.00	do	.25		
		8.00	do	.25		
		8.00	do	.25		
		8.00	do	.17		
		8.00	do	.25		

Record of firing with 3.20-inch breech-loading rifle No.

	Number of fire.	Time.	Powder.		Projectile.		
			Kind.	Weight.	Kind.	Weight.	Elevation.
		1883.		*Lbs.*		*Lbs.*	°
A. M.—Barometer, 30.348; thermometer, 30; relative humidity, 78; wind, 24 miles an hour.	631	Feb. 23	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Hotchkiss rebanded, 1 copper band.	12	−¼
	632	Feb. 23	......do	3	....do	12	−¼
	633	Feb. 23	......do	3	....do	12	−¼
	634	Feb. 23	......do	3	....do	12	−¼
	635	Feb. 23	......do	3	....do	12	−¼
	636	Feb. 23	......do	3	....do	12	−¼
	637	Feb. 23	......do	3	....do	12	−¼
	638	Feb. 23	......do	3	....do	12	−¼
	639	Feb. 23	......do	3	....do	12	−¼
	640	Feb. 23	......do	3	....do	12	−¼
	641	Feb. 23	......do	3	....do	12	−¼
A. M.—Barometer, 30.496; thermometer, 15; relative humidity, 48; wind, 12 miles an hour.	642	Mar. 8	......do	3	....do	12	−¼
	643	Mar. 8	......do	3	....do	12	−¼
	644	Mar. 8	......do	3	....do	12	−¼
	645	Mar. 8	......do	3	....do	12	−¼
	646	Mar. 8	......do	3	....do	13	−¼
	647	Mar. 8	......do	3	....do	12	−¼
	648	Mar. 8	......do	3	....do	12	−¼
	649	Mar. 8	......do	3	....do	12	−¼
	650	Mar. 8	......do	3	....do	12	−¼
	651	Mar. 8	......do	3	....do	12	−¼
	652	Mar. 8	......do	2	....do	12	−¼
	653	Mar. 8	......do	3	....do	12	0
	654	Mar. 8	......do	3	....do	12	0
	655	Mar. 8	......do	3	....do	12	−¼
	656	Mar. 8	......do	3	....do	12	−¼

774, chambered, at Sandy Hook, N. J., &c.—Continued.

Pressure, per square inch of bore.	Instrumental velocity, 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Lbs.	*Feet.*	*Feet.*		*Feet.*		
24,000	1,507	7.50	From rear and slightly left.	0.00	Fired into sand butt to try carriage.	
....	....	8.00		.25		
....	....	8.17		.25		
....	....	8.00		.17		
....	....	8.00		.25		
....	....	8.00		.17		
....	....	8.00		.17		Round 637, right bolt passing into cheek of trail from below, broke.
....	....	8.00		.17		
....	....	8.00		.17		
....	....	8.25		.50		
22,000	1,501	7.50		.00		
						After 641st round, gun washed out, examined, star-gauged, and impressions of bore taken. NOTES.—Gun mounted on carriage modified by Lieut. Col. A. R. Buffington. During all firings in this report (February 7 to 23, inclusive) elevating screw replaced by wooden block at breech of gun. Spring brakes connecting axle with tire of wheel by means of a shoe used to take up a part of recoil. Gun on plank road. Carriage worked well.
24,500	1,497	16.50	From right to left.	......		At round 642 spring brake connecting axle with wheel on left side of carriage was released by firing.
....	....	23.00		......		At round 643 both spring brakes connecting axle with wheels were released by firing.
....	....	8.50		......		
....	....	8.67		0.17		
....	....	8.00		.33		
....	....	10.00		.33		
....	....	8.50		.25		
....	....	8.00		.25		
....	....	8.00		.25		
....	....	8.00		.33		Examination made after 651st round showed that gas check had become scored during preceding 10 rounds; same ground off before continuing the firing.
22,500	1,477	8.00		.33		
....	....	5.50		.29		
....	....	6.00		.17		
....	....	7.50		.25		
....	....	8.00		.33		

Record of firing with 3.20-inch breech-loading rifle No.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.
			Kind.	Weight.	Kind.	Weight.	
		1883.		*Lbs.*		*Lbs.*	°
A. M.—Barometer, 30.496; thermometer, 15; relative humidity, 48; wind, 12 miles an hour.	657	Mar. 8	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Hotchkiss rebanded, 1 copper band.	12	[illegible]
	658	Mar. 8	......do	3	....do	12	[illegible]
	659	Mar. 8	......do	3	....do	12	[illegible]
	660	Mar. 8	......do	3	....do	12	[illegible]
	661	Mar. 8	......do	3	....do	12	[illegible]
A. M.—Barometer, 30.328; thermometer, 26; relative humidity, 64; wind, 3 miles an hour.	662	Mar. 9	......do	3	....do	12	[illegible]
	663	Mar. 9	......do	3	....do	12	[illegible]
	664	Mar. 9	......do	3	....do	12	[illegible]
	665	Mar. 9	......do	3	....do	12	[illegible]
	666	Mar. 9	......do	3	....do	12	[illegible]
	667	Mar. 9	......do	3	....do	12	[illegible]
	668	Mar. 9	......do	3	....do	12	[illegible]
	669	Mar. 9	......do	3	....do	12	[illegible]
	670	Mar. 9	......do	3	....do	12	[illegible]
	671	Mar. 9	......do	3	....do	12	[illegible]
	672	Mar. 9	......do	3	....do	12	[illegible]
	673	Mar. 9	......do	3	....do	12	[illegible]
	674	Mar. 9	......do	3	....do	12	[illegible]
	675	Mar. 9	......do	3	....do	12	[illegible]
	676	Mar. 9	......do	3	....do	12	[illegible]
	677	Mar. 9	......do	3	....do	12	[illegible]
	678	Mar. 9	......do	3	....do	12	[illegible]
	679	Mar. 9	......do	3	....do	12	[illegible]
	680	Mar. 9	......do	3	....do	12	[illegible]
	681	Mar. 9	......do	3	....do	12	[illegible]
P. M.—Barometer, 30.237; thermometer, 34; relative humidity, 72; wind, 12 miles an hour.	682	Mar. 9	......do	3	....do	12	[illegible]
	683	Mar. 9	......do	3	....do	12	[illegible]
	684	Mar. 9	......do	3	....do	12	[illegible]
	685	Mar. 9	......do	3	....do	12	[illegible]
	686	Mar. 9	......do	3	....do	12	[illegible]
	687	Mar. 9	......do	3	....do	12	[illegible]
	688	Mar. 9	......do	3	....do	12	[illegible]
	689	Mar. 9	......do	3	....do	12	[illegible]

774, chambered, at Sandy Hook, N. J., &c.—Continued.

Pressure, per square inch of bore.	Instrumental velocity, 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Lbs.	*Feet.*	*Feet.*		*Feet.*		
....	....	8.00	From right to left.	0.83	Fired into sand butt to try carriage.	
....	....	8.17		.50		
....	....	8.83		.50		
....	....	8.00		.83		
....	....	7.50		.83		After 661st round, gun washed out, examined, and star-gauged; examination showed that gas check had become scored during preceding 10 rounds; same ground off before continuing the firing.
22,500	1,478	8.00	From rear and right.	.33		
....	....	6.25		.22		
....	....	5.83		......		
....	....	7.50		.83		
....	....	7.50		.83		
....	....	7.67		.33		
....	....	8.00		.50		
....	....	8.17		.50		
....	....	8.17		.50		
....	....	8.00		.50		Examination made after 671st round showed that gas check had become scored during preceding 10 rounds; same ground off before continuing the firing.
24,000	1,490	8.00		.50		
....	....	8.00		.50		
....	....	8.00		.50		
....	....	7.83		.50		
....	....	8.00		.50		
....	....	8.00		.50		
....	....	8.00		.83		
....	....	8.25		.50		
....	....	8.00		.83		
....	....	8.00		.50		After 681st round gun washed out, examined, and star-gauged; examination showed that gas check had become scored during preceding 10 rounds; same ground off before continuing the firing.
22,000	1,510	7.50	From front and left.	.25		
....	....	8.00		.50		
....	....	7.75		.50		
....	....	8.00		.50		
....	....	7.75		.50		
....	....	7.75		.50		
....	....	7.75		.50		
....	....	8.00		.25		

Record of firing with 3.20-inch breech-loading rifle No. 74,

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation in degrees.
		1883.		*Lbs.*		*Lbs.*	°
P. M.—Barometer, 30.237; thermometer, 34; relative humidity 72; wind 12 miles an hour.	690	Mar. 9	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Hotchkiss rebanded, 1 copper band.	12	1
	691	Mar. 9	......do	3	....do	12	1
	692	Mar. 9	......do	3	....do	12	1
	693	Mar. 9	......do	3	....do	12	1
	694	Mar. 9	......do	3	....do	12	1
	695	Mar. 9	......do	3	....do	12	1
	696	Mar. 9	......do	3	....do	12	1
	697	Mar. 9	......do	3	....do	12	1
	698	Mar. 9	......do	3	....do	12	1
	699	Mar. 9	......do	3	....do	12	1
	700	Mar. 9	......do	3	....do	12	1
	701	Mar. 9	......do	3	....do	12	1
	702	Mar. 9	......do	3	....do	12	1
	703	Mar. 9	......do	3	....do	12	1
	704	Mar. 9	......do	3	....do	12	1
	705	Mar. 9	......do	3	....do	12	1
	706	Mar. 9	......do	3	....do	12	1
	707	Mar. 9	......do	3	....do	13	1
	708	Mar. 9	......do	3	....do	12	1
	709	Mar. 9	......do	3	....do	12	1
	710	Mar. 9	......do	3	....do	12	1
	711	Mar. 9	......do	3	....do	12	1
	712	Mar. 9	......do	3	....do	12	1
	713	Mar. 9	......do	3	....do	12	1
	714	Mar. 9	......do	3	....do	12	1
	715	Mar. 9	......do	3	....do	12	1
	716	Mar. 9	......do	3	....do	12	1
	717	Mar. 9	......do	3	....do	12	1
	718	Mar. 9	......do	3	....do	12	1
	719	Mar. 9	......do	3	....do	12	1
	720	Mar. 9	......do	3	....do	12	1
	721	Mar. 9	......do	3	....do	12	1

chambered, at Sandy Hook, N. J., &c.—Continued.

Pressure, pounds, per square inch of bore.	Instrumental velocity, 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	Feet.	*Feet.*		*Feet.*		
....	....	7.75	From front and left.	0.50	Fired into sand butt to try carriage.	
....	....	8.50		.50		
23,000	1,500	7.50		.50		
....	....	8.50		.25		
....	....	8.00		.50		
....	....	7.75		.33		
....	....	7.50		.25		
....	....	7.50		.25		
....	....	7.25		.50		
....	....	8.00		.25		
....	....	8.75		.25		
....	....	7.75		.50		After 701st round gun washed out, examined, and star gauged.
22,000	1,487	7.25		.50		
....	....	7.75		.50		
....	....	7.75		.25		
....	....	7.75		.25		
....	....	7.50		.17		
....	....	7.50		.50		
....	....	7.75		.25		
....	....	7.50		.17		
....	....	7.75		.17		
....	....	7.75		.50		
21,000	1,494	7.75		.17		At 712th round bolt fastening trail-handspike socket to trail (right side) broke.
....	....	7.50		.25		
....	....	7.33		.25		
....	....	7.33		.25		
....	....	7.50		.17		
....	....	7.50		.25		At 717th round bolt fastening trail-handspike socket to trail (left side) broke, and trail-handspike and its socket removed.
....	....	8.00		.25		
....	....	7.75		.33		
....	....	7.75		.33		
....	....	7.75		.25		After 721st round gun washed out, examined, and star gauged.

Record of firing with 3.20-inch breech-loading rifle No. 714,

	Number of fire.	Time.	Powder.		Projectile.		Elevation in degrees.
			Kind.	Weight.	Kind.	Weight.	
		1883.		*Lbs.*		*Lbs.*	°
At beginning of firing.—Barometer, 30.018; thermometer, 33; relative humidity 68; wind 21 miles an hour.	722	Mar. 24	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Hotchkiss rebanded, 1 copper band.	12	1
	723	Mar. 24	......do	3	....do	12	1
	724	Mar. 24	......do	3	....do	12	1
	725	Mar. 24	......do	3	....do	12	1
	726	Mar. 24	......do	3	....do	12	1
	727	Mar. 24	......do	3	....do	12	1
	728	Mar. 24	......do	3	....do	12	1
	729	Mar. 24	......do	3	....do	12	1
	730	Mar. 24	......do	3	....do	12	1
	731	Mar. 24	......do	3	....do	12	1
	732	Mar. 24	......do	3	....do	12	1
	733	Mar. 24	......do	3	....do	12	1
	734	Mar. 24	......do	3	....do	12	1
	735	Mar. 24	......do	3	....do	12	1
	736	Mar. 24	......do	3	....do	12	1
	737	Mar. 24	......do	3	....do	12	1
	738	Mar. 24	......do	3	....do	12	1
	739	Mar. 24	......do	3	....do	12	1
	740	Mar. 24	......do	3	....do	12	1
	741	Mar. 24	......do	3	....do	12	1
	742	Mar. 24	......do	3	....do	12	1
	743	Mar. 24	......do	3	....do	12	1
	744	Mar. 24	......do	3	....do	12	1
	745	Mar. 24	......do	3	....do	12	1
	746	Mar. 24	......do	3	....do	12	1
	747	Mar. 24	......do	3	....do	12	1
	748	Mar. 24	......do	3	....do	12	1
	749	Mar. 24	......do	3	....do	12	1
	750	Mar. 24	......do	3	....do	12	1
	751	Mar. 24	......do	3	....do	12	1
	752	Mar. 24	......do	3	....do	12	1
	753	Mar. 24	......do	3	....do	12	1
	754	Mar. 24	......do	3	....do	12	1
	755	Mar 24	......do	3	....do	12	1
	756	Mar. 24	......do	3	....no	12	1

chambered, at Sandy Hook, N. J., &c.—Continued.

Pressure, pounds, per square inch of bore.	Instrumental velocity, 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	Feet.	*Feet.*		*Feet.*	
21,000	1,494	7.83	From rear and right.	0.50	Fired into sand butt to try carriage.
....	....	8.00		.50	
....	....	7.83		.50	
....	....	7.17		.50	
....	....	7.50		.83	
....	....	7.50		.83	
....	....	7.50		.83	
....	....	8.00		.50	
....	....	8.00		.50	
....	....	8.83		.50	After 731st round examination made showed that gas-check and obturator plate had become scored during the previous 10 rounds.
22,500	1,518	7.17		.67	
....	....	8.00		.50	
....	....	7.83		.50	
....	....	7.83		.50	
....	....	7.67		.50	
....	....	7.67		.50	
....	....	7.67		.50	
....	....	8.00		.50	
....	....	8.00		.50	
....	....	7.67		.50	After 741st round gun washed out, examined, and star gauged. Obturator-plate ground down before firing round 742.
24,500	1,507	7.83		.50	
....	....	7.83		.50	
....	....	8.00		.83	
....	....	7.83		.50	
....	....	8.00		.50	
....	....	8.00		.83	
....	....	8.00		.67	
....	....	8.00		.67	
....	....	7.83		.67	
....	....	8.00		.50	
24,500	1,520	7.50		.67	
....	....	8.00		.50	
....	....	8.00		.83	
....	....	8.00		.83	
....	....	8.17		.50	

Record of firing with 3.20-inch breech-loading rifle No. 7¼,

	Number of fire.	Time.	Powder.		Projectile.		
			Kind.	Weight.	Kind.	Weight.	Elevation.
		1883.		*Lbs.*		*Lbs.*	°
At end of firing.—Barometer, 30.070; thermometer, 35; relative humidity, 69; wind, 24 miles an hour.	757	Mar. 24	Du Pont's I.K.B. Density, 1.725; granulation, 2,200.	3	Hotchkiss, rebanded, 1 copper band.	12	−¼
	758	Mar. 24	......do	3	....do	12	−¼
	759	Mar. 24	......do	3	....do	12	−¼
	760	Mar. 24	...... do	3	....do	12	−¼
	761	Mar. 24	......do	3	....do	12	−¼
	762	Mar. 24	......do	3	....do	12	−¼
	763	Mar. 24	......do	3	....do	12	−¼
	764	Mar. 24	......do	3	....do	12	−¼
	765	Mar. 24	......do	3	....do	12	−¼
	766	Mar. 24	......do	3	....do	12	−¼
	767	Mar. 24	......do	3	....do	12	−¼
	768	Mar. 24	......do	3	....do	12	−¼
	769	Mar. 24	......do	3	....do	12	−¼
	770	Mar. 24	......do	3	....do	12	−¼
	771	Mar. 24	......do	3	....do	12	−¼
	772	Mar. 24	......do	3	....do	12	−¼
	773	Mar. 24	......do	3	....do	12	−¼
	774	Mar. 24	......do	3	....do	12	−¼
	775	Mar. 24	......do	3	....do	12	−¼
	776	Mar. 24	......do	3	....do	12	−¼
	777	Mar. 24	......do	3	....do	12	−¼
	778	Mar. 24	......do	3	....do	12	−¼
	779	Mar. 24	......do	3	....do	12	−¼
	780	Mar. 24	......do	3	....do	12	−¼
	781	Mar. 24	......do	3	....do	12	−¼
	782	Mar. 24	......do	3	....do	12	−¼
	783	Mar. 24	......do	3	....do	12	−¼
	784	Mar. 24	......do	3	....do	12	−¼
	785	Mar. 24	......do	3	...do	12	−¼
	786	Mar. 24	......do	3	....do	12	−¼
	787	Mar. 24	......do	3	....do	12	−¼
	788	Mar. 24	......do	3	....do	12	−¼
	789	Mar. 24	......do	3	....do	12	−¼
	790	Mar. 24	......do	3	....do	12	−¼
	791	Mar. 24	......do	3	....do	12	−¼

chambered, at Sandy Hook, N. J., &c.—Continued.

Pressure per square inch of bore.	Instrumental velocity 95 feet from gun.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Lbs.	*Feet.*	*Feet.*		*Feet.*		
....	....	7.83	From rear and right.	0.50	Fired into sand butt to try carriage.	
....	....	8.00		.83		
....	....	8.00		.50		
....	....	7.50		.33		
....	....	7.50		.50		After round 761 gun washed out, examined, and star-gauged.
19,000	1,453	7.50		.25		
....	....	7.50		.67		
....	....	8.00		.25		
....	....	7.50		.50		
....	....	7.50		.83		
....	....	7.33		.17		
....	....	8.00		.50		
....	....	8.00		.83		
....	....	8.17		.33		
....	....	8.00		.50		
24,000	1,506	7.83		.50		
....	....	8.00		.83		
....	....	8.17		.17		
....	....	7.83		.83		
....	....	7.33		.25		
....	....	8.00		.83		
....	....	7.67		.67		
....	....	7.83		.67		
....	....	7.67		.50		
....	....	8.17		.83		After round 781 gun washed out, examined, and star-gauged.
22,500	1,501	7.83		.83		
....	....	8.50		.33		
....	....	7.50		.67		
....	....	8.17		.67		
....	....	7.83		.67		
....	....	8.00		.83		Gas cuts show in six different places on face of gas check, one crossing all cannelures to outside edge. These cuts are enlargements of cuts previously reported. Face of gas check has been ground down three times during the last 70 rounds.
....	....	8.00		.83		
....	....	7.50		.67		
....	....	8.00		.83		
....	....	7.50		.67		

Record of firing with 3.20-inch breech-loading rifle No. 774,

	Number of fire.	Time.	Powder.		Projectile.		Elevation.
			Kind.	Weight.	Kind.	Weight.	
		1883.		*Lbs.*		*Lbs.*	°
Barometer, 29.927; thermometer, 42; relative humidity, 43; wind, 20 miles an hour.	792	Mar. 28	Du Pont's I.K.B. Density, 1.725; granulation, 2,200.	3	Hotchkiss, rebanded, 1 copper band.	12	5
	793	Mar. 28	......do	3	....do	12	5
	794	Mar. 28	......do	3	....do	12	5
	795	Mar. 28	......do	3	....do	12	5
	796	Mar. 28	......do	3	....do	12	5
	797	Mar. 28	......do	3	....do	12	5
	798	Mar. 28	......do	3	....do	12	5
	799	Mar. 28	......do	3	....do	12	5
	800	Mar. 28	......do	3	....do	12	5
	801	Mar. 28	......do	3	....do	12	5
	802	Mar. 28	......do	3	....do	12	10
	803	Mar. 28	......do	3	....do	12	10
	804	Mar. 28	......do	3	....do	12	10
	805	Mar. 28	......do	3	....do	12	10
	806	Mar. 28	......do	3	....do	12	10
	807	Mar. 28	......do	3	....do	12	10
	808	Mar. 28	......do	3	....do	12	10
	809	Mar. 28	......do	3	....do	12	10
	810	Mar. 28	......do	3	....do	12	10
	811	Mar. 28	......do	3	....do	12	10
	812	Mar. 28	......do	3	....do	12	15
	813	Mar. 28	......do	3	....do	12	15
	814	Mar. 28	......do	3	....do	12	15
	815	Mar. 28	......do	3	....do	12	15
	816	Mar. 28	......do	3	....do	12	15
	817	Mar. 28	......do	3	....do	12	15
	818	Mar. 28	......do	3	....do	12	15
	819	Mar. 28	......do	3	....do	12	15
	820	Mar. 28	......do	3	....do	12	15
	821	Mar. 28	......do	3	....do	12	15
	822	Mar. 28	......do	3	....do	12	15
Barometer, 30.100; thermometer, 33; relative humidity, 68; wind, 4 miles an hour.	823	Mar. 29	......do	3	....do	12	20
	824	Mar. 29	......do	3	....do	12	20
	825	Mar. 29	......do	3	....do	12	20
	826	Mar. 29	......do	3	....do	12	20

chambered, at Sandy Hook, N. J., &c.—Continued.

Time of flight.	Range.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Secs.	*Yards.*	*Feet.*		*Feet.*	
......	2,329	6.50	From rear and slightly left.	0.50	Fired out to sea for ranges. Before firing round 792 new gas check and vent fitted to gun.
......	2,481	6.83		.17	
7¾	2,537	6.00		.17	
7½	2,491	5.83		.25	
7½	2,456	6.50		.17	
7¼	2,597	6.25		.17	
7½	2,482	6.00		.33	
7¾	2,556	6.50		.25	
7½	2,498	6.67		.25	
7¾	2,473	6.17		.33	
18¼	4,061	5.50		.50	
......	4,107	[illegible] 58		.75	
13¼	4,011	5.83		.67	
13	4,003	6.00		.75	
13	3,867	5.83		.50	
13½	3,926	5. 3		.42	
13½	3,977	6.00		.33	
13	3,914	6.17		.50	
13¼	3,986	5.50		.42	
13	4,011	6.00		.58	
18½	Lost ..	4.50		.67	
18¼	4,693	4.50		.50	
18½	5,023	4.42		.58	
18½	5,056	4.58		.50	
18½	5,056	4.33		.42	
18¼	5,021	4.33		.50	
18¾	5,123	4.50		.42	
18¼	5,014	4.17		.33	
18¾	4,991	5.00		.25	
18	4,784	4.67		.25	
18¼	5,014	4.92		.25	At round 822 gun washed out, examined, and star-gauged.
23½	Lost ..	4.00	From right and front.	.25	
23½	Lost ..	5.00		.17	
23¼	Lost ..	4.50		.17	
23¼	Lost ..	4.75		.25	

Record of firing with 3.20-inch breech-loading rifle No. 714,

	Number of fire.	Time.	Powder.		Projectile.		Elevation.
			Kind.	Weight.	Kind.	Weight.	
		1883.		*Lbs.*		*Lbs.*	°
Barometer, 29.927; thermometer, 42; relative humidity, 43; wind, 20 miles an hour.	792	Mar. 28	Du Pont's I.K.B. Density, 1.725; granulation, 2,200.	8	Hotchkiss, rebanded, 1 copper band.	12	5
	793	Mar. 28	......do	8	....do	12	5
	794	Mar. 28	......do	8	....do	12	5
	795	Mar. 28	......do	8	....do	12	5
	796	Mar. 28	......do	8	....do	12	5
	797	Mar. 28	......do	8	....do	12	5
	798	Mar. 28	......do	8	....do	12	5
	799	Mar. 28	......do	8	....do	12	5
	800	Mar. 28	......do	8	....do	12	5
	801	Mar. 28	......do	8	....do	12	5
	802	Mar. 28	......do	8	....do	12	10
	803	Mar. 28	......do	8	....do	12	10
	804	Mar. 28	......do	8	....do	12	10
	805	Mar. 28	......do	8	....do	12	10
	806	Mar. 28	......do	8	....do	12	10
	807	Mar. 28	......do	8	....do	12	10
	808	Mar. 28	......do	8	....do	12	10
	809	Mar. 28	......do	8	....do	12	10
	810	Mar. 28	......do	8	....do	12	10
	811	Mar. 28	......do	8	....do	12	10
	812	Mar. 28	......do	8	....do	12	15
	813	Mar. 28	......do	8	....do	12	15
	814	Mar. 28	......do	8	....do	12	15
	815	Mar. 28	......do	8	....do	12	15
	816	Mar. 28	......do	8	....do	12	15
	817	Mar. 28	......do	8	....do	12	15
	818	Mar. 28	......do	8	....do	12	15
	819	Mar. 28	......do	8	....do	12	15
	820	Mar. 28	......do	8	....do	12	15
	821	Mar. 28	......do	8	....do	12	15
	822	Mar. 28	......do	8	....do	12	15
Barometer, 30.100; thermometer, 53; relative humidity, 68; wind, 4 miles an hour.	823	Mar. 29	......do	8	....do	12	20
	824	Mar. 29	......do	8	....do	12	20
	825	Mar. 29	......do	8	....do	12	20
	826	Mar. 29	......do	8	....do	12	20

chambered, at Sandy Hook, N. J., &c.—Continued.

Time of flight.	Range.	Recoil.	Direction of wind as regards line of fire.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Secs.	*Yards.*	*Feet.*		*Feet.*	
......	2,329	6.50	From rear and slightly left.	0.50	Fired out to sea for ranges. Before firing round 792 new gas check and vent fitted to gun.
......	2,481	6.83		.17	
7¾	2,537	6.00		.17	
7½	2,491	5.83		.25	
7½	2,456	6.50		.17	
7¼	2,597	6.25		.17	
7½	2,482	6.00		.33	
7¾	2,556	6.50		.25	
7½	2,498	6.67		.25	
7¾	2,473	6.17		.33	
13¼	4,061	5.50		.50	
......	4,107	5.58		.75	
13¼	4,011	5.83		.67	
13	4,003	6.00		.75	
18	3,867	5.83		.50	
13½	3,926	5. 3		.42	
13½	3,977	6.00		.83	
13	3,914	6.17		.50	
13¼	3,986	5.50		.42	
13	4,011	6.00		.58	
18½	Lost ..	4.50		.67	
18¼	4,693	4.50		.50	
18½	5,023	4.42		.58	
18½	5,056	4.58		.50	
18½	5,056	4.33		.42	
18¼	5,021	4.33		.50	
18¾	5,123	4.50		.42	
18¼	5,014	4.17		.33	
18¾	4,991	5.00		.25	
18	4,784	4.67		.25	
18¼	5,014	4.92		.25	At round 822 gun washed out, examined, and star-gauged.
23½	Lost ..	4.00	From right and front.	.25	
23½	Lost ..	5.00		.17	
23¼	Lost .	4.50		.17	
23¼	Lost ..	4.75		.25	

Record of firing with 3.20-inch breech-loading rifle, No. 774,

	No. of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation in degrees.	Deflection. Range.	Deflection. Right.	Deflection. Left.
		1883.		*Lbs.*		*Lbs. oz.*		*Yards.*	*Yds.*	*Yds.*
P.M.—Barometer, 30.158; thermometer, 62; relative humidity, 50; wind, 8 miles an hour.	827	May 9	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Hotchkiss shell resaboted with Bormann fuze in base (shell unfilled).	11 12	0	....	...	....
A.M.—Barometer, 29.903; thermometer, 62; relative humidity, 50; wind, 4 miles an hour.	828	May 16		3	Hotchkiss resaboted shot. 1 copper band.	12 00	0	....	...	....
	829	May 16		3	....do	12 00	0	....	...	....
A.M.—Barometer, 29.958; thermometer, 67; relative humidity, 100; wind, 37 miles an hour.	830	June 27		3	....do	12 00	3	....	...	....
	831	June 27		3	....do	12 00	3	....	...	....
	832	June 27		3	....do	12 00	3	....	...	....
	833	June 27		3	....do	12 00	3	....	...	....
	834	June 27		3	....do	12 00	3	....	...	....
	835	June 27		3	....do	12 00	3	....	...	....
	836	June 27		3	....do	12 00	3	....	...	....
	837	June 27		3	....do	12 00	3	....	...	....
	838	June 27		3	....do	12 00	3	....	...	....
	839	June 27		3	....do	12 00	3	....	...	....
A.M.—Barometer, 29.967; thermometer, 76; relative humidity, 67; wind, 12 miles an hour.	840	June 28		3	....do	12 00	20	6, 001	98	....
	841	June 28		3	....do	12 00	20	....	....	....
	842	June 28		3	....do	12 00	20	5, 860	16	....
	843	June 28		3	....do	12 00	20	6, 036	....	37
	844	June 28		3	....do	12 00	20	5, 612	2	....
	845	June 28		3	....do	12 00	20	5, 659	8	....
	846	June 28		3	....do	12 00	20	....	....	....
	847	June 28		3	....do	12 00	20	....	....	....
	848	June 28		3	....do	12 00	20	5, 892	....	7
	849	June 28		3	....do	12 00	20	6, 096	2	....

chambered, at Sandy Hook, N. J., &c.—Continued.

Recoil.	Direction of wind as regards	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
Feet.		*Feet.*		
7.75	From left to right.	......	Fired into sand butt to try fuze	NOTE.—Shell recovered from sand butt and fuze found to have been blown in.
26.17	From rear.	......	Fired into sand butt to try carriage. Gun on plank road.	Spring-brakes connecting axle with tire of wheel by means of a shoe used to take up part of recoil removed previous to firing this round. NOTE.—Bolt fastening axle brace to cheek of carriage broke in round 828.
8.50		......		Spring-brakes on during this round.
			3.2-inch experimental steel gun-carriage from Watervleit Arsenal with trail plate strengthened with steel angle plate.	
12.58	From front and left 45°, 37 miles an hour.	......	Fired into sand butt to try carriage. Carriage on plank road and planks wet from rain-storm.	Rounds 830 and 831 trail handspike left forward on trail—in following rounds trail handspike left down in position for maneuvering. After round 839 it was noticed that trail handspike was slightly bent; straightened before firing round 840 and left down during following rounds. Trail handspike commenced bending again at round 841—curvature slightly increased at each succeeding round. At round 847 right brake-rod cracked at weld in neck.
14.00		1.50		
14.42		1.58		
14.00		1.58		
14.33		1.25		
15.00		1.58		
14.50		1.58		
15.00		1.50		
13.33		1.58		
15.83		1.58		
4.50	From front and right 65°, 12 miles an hour.	1.00	Fired over water. Carriage on plank road and planks dry. Brakes over tire of wheels forced down.	
4.67		1.00		
4.50		1.00		
4.83		1.17		
5.17		1.00		
5.33		1.42	Brakes over tire of wheels easy.	
5.17		1.00		
5.25		1.17		
5.17		1.83		
5.08		1.17		

Table of enlargements of 3.20-inch breech-

Inches from muzzle.	Oct. 23, 1880. Diameter after 162 rounds and after reboring.	Enlargements after—											
		306 rounds. Dec. 21, 1882.	360 rounds. Jan. 26, 1883.	380 rounds. Jan. 26, 1883.	400 rounds. Jan. 27, 1883.	420 rounds. Jan. 27, 1883.	440 rounds. Jan. 29, 1883.	460 rounds. Feb. 7, 1883.	480 rounds. Feb. 7, 1883.	500 rounds. Feb. 8, 1883.	520 rounds. Feb. 8, 1883.	540 rounds. Feb. 8, 1883.	560 rounds. Feb. 14, 1883.
		Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
54	3.213	0.003	0.006	0.008	0.011	0.011	0.012	0.012	0.012	0.012	0.012	0.012	[illegible]
53½	3.211	.005	.007	.008	.009	.011	.011	.011	.011	.011	.011	.012	[illegible]
53	3.211	.005	.007	.007	.008	.010	.010	.010	.010	.010	.010	.010	[illegible]
52½	3.212	.003	.006	.006	.006	.008	.008	.008	.008	.008	.008	.008	[illegible]
52	3.214	.001	.004	.004	.004	.005	.005	.005	.005	.005	.005	.006	[illegible]
51½	3.213	.002	.005	.005	.005	.006	.006	.006	.006	.006	.006	.006	[illegible]
51	3.213	.001	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	[illegible]
50½	3.206	.006	.009	.009	.009	.010	.010	.010	.010	.010	.011	.011	[illegible]
50	3.206	.004	.009	.009	.009	.009	.009	.009	.009	.009	.010	.010	[illegible]
49½	3.206	.002	.008	.008	.008	.008	.008	.008	.008	.008	.009	.009	[illegible]
49	3.206	.002	.008	.008	.008	.008	.008	.008	.008	.008	.008	.008	[illegible]
48½	3.206	.003	.008	.008	.008	.008	.008	.008	.008	.008	.008	.008	[illegible]
48	3.207	.005	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	[illegible]
47½	3.209	.001	.006	.006	.007	.007	.007	.007	.007	.007	.009	.009	[illegible]
47	3.208	.002	.007	.007	.007	.007	.008	.008	.008	.008	.008	.008	[illegible]
46½	3.208	.002	.007	.007	.007	.007	.007	.007	.007	.007	.008	.008	[illegible]
46	3.208	.002	.006	.006	.006	.006	.006	.006	.006	.006	.007	.008	[illegible]
45½	3.208	.002	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	[illegible]
45	3.209	.001	.004	.004	.004	.005	.005	.005	.005	.005	.005	.005	[illegible]
44½	3.210	.000	.001	.001	.004	.004	.004	.004	.004	.004	.004	.004	[illegible]
44	3.209	.001	.002	.002	.005	.005	.005	.005	.005	.005	.005	.005	[illegible]
43½	3.211	.000	.001	.001	.003	.003	.003	.003	.003	.003	.003	.003	[illegible]
43	3.211	.000	.001	.001	.003	.004	.004	.004	.004	.004	.004	.004	[illegible]
42½	3.212	.000	.001	.001	.002	.003	.003	.003	.003	.003	.003	.003	[illegible]
42	3.211	.001	.002	.002	.003	.004	.004	.004	.004	.004	.004	.004	[illegible]
41½	3.208	.004	.005	.005	.007	.007	.007	.007	.007	.007	.007	.007	[illegible]
41	3.211	.000	.003	.003	.003	.004	.004	.004	.004	.004	.004	.004	[illegible]
40½	3.208	.002	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	[illegible]
40	3.210	.000	.003	.003	.004	.004	.004	.004	.004	.004	.004	.004	[illegible]
38	3.212	.000	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	[illegible]
36	3.208	.002	.005	.005	.006	.007	.007	.007	.007	.007	.007	.007	[illegible]
34	3.208	.000	.005	.005	.005	.006	.006	.006	.006	.006	.006	.006	[illegible]
32	3.210	.000	.001	.001	.002	.003	.003	.003	.003	.003	.003	.003	[illegible]
30	3.210	.000	.002	.002	.003	.003	.003	.003	.003	(*)	(*)	(*)	(*)
28	3.209	.001	.002	.002	.002	.004	.004	.004	.004	.004	.004	.004	[illegible]
26	3.212	.000	.000	.000	.000	.001	.001	.001	.001	.001	.001	.001	[illegible]
24	3.213	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	[illegible]
22	3.213	.000	.000	.000	.000	.001	.001	.001	.001	.001	.001	.001	[illegible]
20	3.212	.000	.000	.000	.000	.001	.001	.001	.001	.001	.001	.001	[illegible]
18	3.212	.000	.000	.000	.002	.003	.003	.003	.003	.003	.003	.003	[illegible]
16	3.213	.000	.000	.000	.000	.001	.001	.001	.001	.001	.001	.001	[illegible]
14	3.211	.000	.000	.000	.000	.002	.002	.002	.002	.002	.002	.002	[illegible]
12	3.212	.000	.000	.000	.002	.002	.002	.002	.002	.002	.002	.002	[illegible]
10	3.213	.000	.000	.000	.001	.002	.002	.002	.002	.002	.002	.002	[illegible]
8	3.208	.000	.001	.002	.002	.004	.004	.004	.004	.004	.004	.004	[illegible]
6	3.211	.000	.000	.000	.000	.001	.001	.001	.001	.001	.001	.001	[illegible]
4	3.218	.000	.000	.000	.001	.001	.001	.001	.001	.001	.002	.002	[illegible]
2	3.208	.003	.007	.007	.007	.007	.008	.008	.008	.008	.008	.008	[illegible]
1	3.205	.001	.001	.001	.001	.002	.002	.002	.002	.002	.002	.002	[illegible]

* Cavity.

REMARKS.—Three series of star-gaugings after 580 rounds: 1st. When the gun was warm; 2d. When th *loading rifle, No. 774, chambered.*

Enlargements after—													
580 rounds. Feb. 14, 1883.	580 rounds. Feb. 19, 1883.	580 rounds. Feb. 19, 1883.	600 rounds. Feb. 23, 1883.	620 rounds. Feb. 23, 1883.	641 rounds. Feb. 23, 1883.	661 rounds. Mar. 8, 1883.	681 rounds. Mar. 9, 1883.	701 rounds. Mar. 9, 1883.	721 rounds. Mar. 9, 1883.	741 rounds. Mar. 24, 1883.	761 rounds Mar. 24, 1883.	781 rounds. Mar. 24, 1883.	822 rounds. Mar. 28, 1883.
Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
0.012	0.011	0.012	0.010	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
.012	.010	.010	.011	.011	.012	.011	.011	.012	.012	.010	.011	.010	.011
.009	.009	.009	.010	.010	.010	.009	.009	.009	.009	.009	.009	.009	.009
.008	.007	.007	.009	.008	.008	.008	.008	.008	.007	.008	.008	.008	.008
.005	.005	.005	.006	.006	.006	.005	.005	.005	.005	.005	.005	.005	.005
.006	.005	.005	.007	.007	.007	.005	.005	.006	.005	.005	.005	.005	.005
.006	.005	.004	.006	.006	.005	.005	.005	.005	.004	.004	.004	.004	.005
.012	.010	.009	.013	.010	.011	.010	.010	.010	.009	.010	.010	.010	.010
.010	.009	.008	.010	.010	.010	.009	.010	.009	.009	.009	.009	.009	.009
.009	.008	.007	.009	.009	.009	.009	.010	.009	.009	.008	.008	.008	.008
.008	.007	.005	.009	.009	.009	.008	.009	.009	.009	.008	.008	.008	.007
.008	.008	.005	.009	.009	.009	.008	.008	.009	.009	.008	.011	.008	.007
.007	.007	.006	.007	.008	.008	.007	.007	.011	.010	.007	.009	.010	.010
.007	.006	.006	.007	.007	.007	.005	.007	.008	.007	.007	.007	.007	.008
.008	.007	.007	.008	.008	.009	.007	.009	.008	.008	.008	.007	.007	.007
.008	.007	.007	.008	.009	.009	.008	.009	.008	.008	.008	.007	.008	.008
.007	.006	.007	.008	.009	.008	.008	.008	.008	.008	.008	.008	.007	.007
.007	.006	.007	.008	.009	.008	.008	.008	.008	.008	.008	.007	.007	.008
.006	.006	.006	.007	.008	.007	.006	.007	.007	.007	.006	.006	.006	.007
.005	.004	.005	.005	.005	.006	.005	.005	.005	.006	.005	.005	.005	.005
.005	.005	.006	.007	.007	.007	.006	.007	.006	.006	.006	.006	.005	.006
.003	.002	.004	.005	.005	.005	.004	.005	.004	.004	.004	.004	.003	.002
.003	.002	.004	.005	.004	.004	.004	.004	.004	.004	.004	.004	.004	.002
.003	.002	.003	.004	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003
.003	.002	.004	.004	.004	.004	.004	.004	.003	.004	.004	.004	.003	.004
.006	.005	.007	.007	.007	.007	.006	.007	.007	.007	.006	.007	.006	.007
.003	.002	.004	.004	.004	.004	.003	.004	.004	.004	.003	.004	.004	.003
.006	.005	.007	.007	.007	.007	.006	.007	.007	.006	.006	.006	.006	.006
.003	.003	.005	.005	.005	.005	.004	.004	.005	.004	.004	.004	.004	.003
.002	.001	.002	.003	.003	.003	.001	.003	.002	.004	.003	.002	.002	.001
.004	.004	.006	.007	.007	.007	.005	.006	.006	.006	.005	.006	.004	.004
.004	.003	.006	.007	.006	.007	.005	.006	.006	.006	.006	.006	.004	.003
.001	.000	.003	.004	.002	.004	.002	.002	.002	.001	.001	.002	.001	.001
(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
.002	.002	.004	.005	.005	.004	.003	.005	.002	.002	.002	.004	.002	.003
.001	.000	.003	.001	.001	.002	—.001	.001	.000	.000	—.001	.002	.000	—.001
—.002	—.003	.001	.001	.000	.001	—.001	.001	.000	.000	.001	.002	—.001	.001
—.001	—.003	.001	.001	.000	.001	.000	.001	—.002	.000	.001	.001	—.002	—.002
—.001	—.002	.001	.001	.000	.001	—.001	.000	.000	—.001	—.001	.000	—.002	—.002
.000	.001	.001	.001	.001	.002	.000	.000	.002	.001	.002	.002	.002	.001
—.001	—.001	.001	.001	.001	.001	—.001	.001	.000	.000	.001	.001	—.002	—.001
.000	—.001	—.001	.000	.000	.001	—.001	.000	.000	.000	—.001	.001	—.001	—.001
—.001	—.001	.000	.002	.000	.001	—.001	.000	.001	.001	.000	.002	.000	—.001
.000	.001	.000	.001	—.001	.001	.001	.002	.001	.001	.001	.000	—.001	—.001
.002	.001	.002	.003	.002	.004	.001	.003	.002	.002	.003	.002	.002	.002
—.001	.000	.001	.002	.003	.000	—.001	—.001	—.001	—.001	—.001	.002	—.001	—.001
.002	.001	.000	.002	.002	.002	.002	.003	.002	.002	.002	.002	.002	.002
.001	—.001	.000	—.001	—.001	.003	.000	.002	.002	.002	.007	.003	.002	.002
.002	.004	.002	.002	.002	.002	.002	.004	.003	.004	.003	.003	.002	.003

* Cavity.

gun was cold; 3d. Gun cold and points of star-gauge on different lands from the other star-gauge records.

Table of enlarge

CHAM

Inches from breech.	Dec. 12, 1882. Diameter of chamber after 306 rounds.	Enlargements after—										
		306 rounds. Dec. 21, 1882.	360 rounds. Jan. 26, 1883.	380 rounds. Jan. 26, 1883.	400 rounds. Jan. 27, 1883.	420 rounds. Jan. 27, 1883.	440 rounds. Jan. 29, 1883.	460 rounds. Feb. 7, 1883.	480 rounds. Feb. 7, 1883.	500 rounds. Feb. 8, 1883.	520 rounds. Feb. 8, 1883.	540 rounds. Feb. 8, 1883.	[illegible] rounds. Feb. 14, [illegible]
		Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
15	3.784	....	—0.002	0.001	0.001	0.001	0.000	0.001	0.001	0.002	0.002	0.002	[illegible]
14½	3.789	....	.000	.001	—.003	.002	.000	.004	.004	.005	.004	.004	[illegible]
14	3.787	....	—.002	.001	.000	.002	.000	.002	.002	.002	.002	.002	[illegible]
13½	3.787	....	—.001	.001	.001	.001	.001	.002	.002	.003	.003	.003	[illegible]
13	3.786	....	—.001	.002	.002	.002	.002	.004	.003	.004	.004	.004	[illegible]
12½	3.787	....	.000	.003	.003	.004	.002	.005	.005	.005	.005	.003	[illegible]
12	3.784	....	.004	.005	.005	.007	.005	.006	.007	.008	.007	.007	[illegible]
11½	3.790	....	.004	.000	.000	.002	.002	.004	.004	.006	.005	.005	[illegible]
11	3.792	....	—.001	.002	.000	.001	.003	.002	.003	.003	.003	.003	[illegible]
10½	3.792	....	—.001	.002	.000	.001	.002	.002	.002	.003	.003	.003	[illegible]
10	3.787	....	.003	.004	.005	.007	.003	.003	.005	.003	.005	.002	[illegible]
9½	3.788	....	—.002	.000	.001	.002	—.001	.002	.001	.002	.003	.001	[illegible]
9	3.787	....	—.001	.001	.002	.003	.001	.003	.003	.003	.003	.002	[illegible]

REMARKS.—Three series of star-gaugings after 580 rounds; 1st. When the gun was warm; 2d. When the *ments, &c.*—Continued.

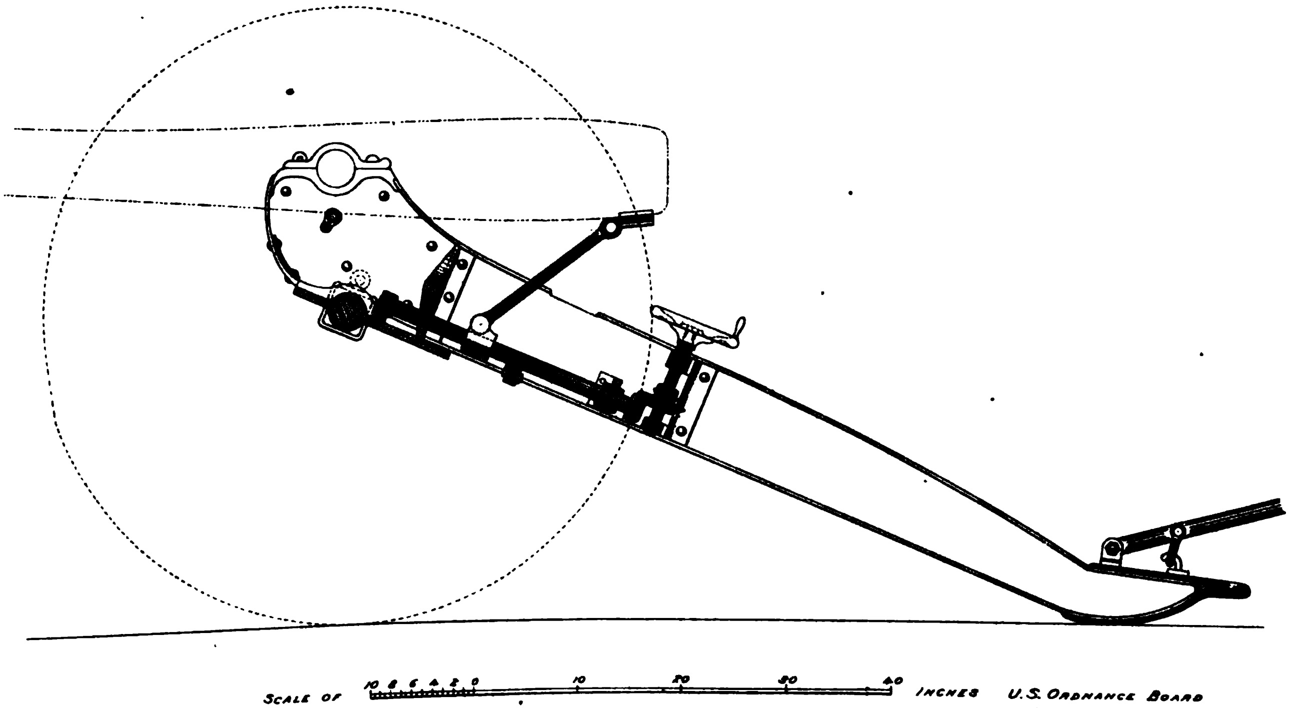
BER.

Enlargements after—													
580 rounds. Feb. 14, 1883.	580 rounds. Feb. 19, 1883.	580 rounds. Feb. 19, 1883.	600 rounds. Feb. 23, 1883.	620 rounds. Feb. 23, 1883.	641 rounds. Feb. 23, 1883.	661 rounds. Mar. 8, 1883.	681 rounds. Mar. 9, 1883.	701 rounds. Mar. 9, 1883.	721 rounds. Mar. 9, 1883.	741 rounds. Mar. 24, 1888.	761 rounds. Mar. 24, 1883.	781 rounds. Mar. 24, 1883.	822 rounds. Mar. 28, 1883.
Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
0.002	0.001	0.000	0.002	0.002	0.002	0.001	0.001	0.001	0.002	0.002	0.001	0.002	0.001
.005	.000	.001	.002	.004	.005	.001	.004	.002	.002	.004	.003	.002	.000
.002	— .001	— .001	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002
.002	.000	.000	.002	.003	.003	.002	.002	.001	.002	.002	.002	.003	.002
.003	.000	.001	.003	.004	.004	.003	.002	.000	.004	.003	.003	.003	.004
.006	.002	.002	.003	.004	.006	.003	.004	.003	.003	.003	.004	.004	.004
.007	.005	.005	.006	.006	.006	.006	.006	.006	.007	.007	.007	.007	.007
.004	.002	.001	.005	.005	.004	.005	.002	.002	.006	.003	.002	.005	.006
.004	.001	.002	.003	.003	.003	.003	.001	.001	.003	.002	.002	.003	.003
.003	.000	.000	.002	.003	.003	.002	.003	.001	.003	.002	.002	.002	.003
.002	.000	.006	.004	.003	.004	.002	.008	.007	.003	.003	.007	.005	.002
.002	— .001	.004	.002	.002	.002	.001	.002	.001	.002	.002	.001	.001	.002
.004	— .001	.004	.004	.002	.003	.002	.003	.003	.003	.003	.002	.002	.004

gun was cold; 3d. Gun cold and points of star-gauge on different lands from the other star-gauge records.

STEEL FIELD CARRIAGE FOR 3·2 INCH B. L. RIFLE

— WITH FLANGED TRAIL PLATES —

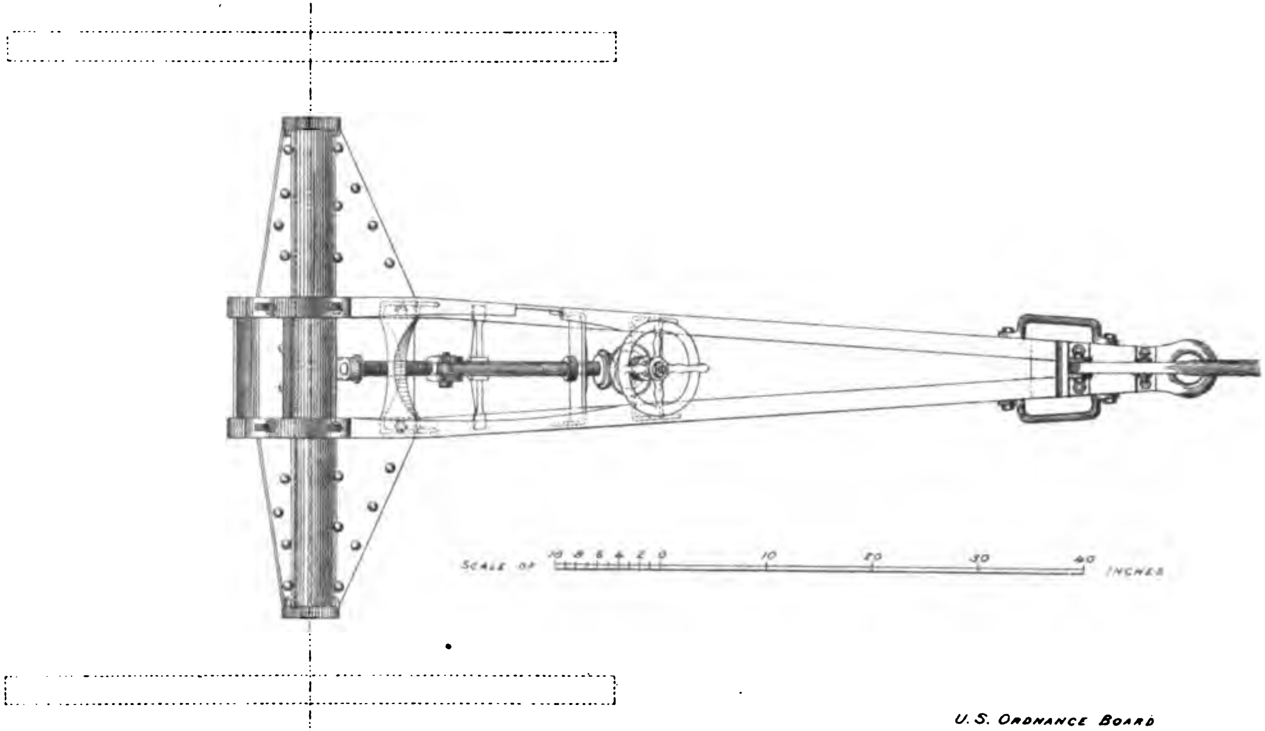


U.S. ORDNANCE BOARD
GOVERNORS ISLAND JULY 18TH 1883.

PLATE II.

STEEL FIELD CARRIAGE FOR 3·2 INCH B. L. RIFLE

— WITH FLANGED TRAIL PLATES —



U. S. ORDNANCE BOARD
GOVERNORS ISLAND JULY 18TH 1883.

instructions were received to alter a carriage as shown in the drawings, which latter were returned.

The carriage selected for alteration was a 10-inch casemate carriage with double cheek-plates of the latest type, and the changes were made as follows:

1. The trunnion beds of the top carriage were enlarged and replaced by beds which fitted the false trunnions required to overcome the counter preponderance of the converted gun.
2. V-plates of bronze were fitted to the front and rear ends of the cheeks in order to receive steel truck wheels. By cutting away the forward part of the shoe the front wheels were permitted to bear upon the chassis rail when the gun was in battery and the rear wheels were thrown into gear.
3. Wedge-shaped rails were bolted to the upper surface of the chassis, so that when the gun recoiled the rear truck wheels would bear upon the wedges, and the front wheels would thereby be caused to bear also.
4. An elevating arc actuated by worm gearing was supplied, in order to elevate and depress the gun.
5. A retraction gear to be used for withdrawing the gun from battery was added.
6. A hydraulic cylinder was placed between the chassis rails, and contained a perforated piston head. The piston rod was connected with a heavy cross-head bolted to the rear transom of the top carriage, while strong struts connected the cross-head with the front bottom transom of the carriage.
7. A rack with a pawl was so arranged as to hold the gun in place at the position it had reached after recoil.

The trial of the carriage commenced after the alterations were completed on June 8, 1883, by firing an 8-inch rifle with a charge of 25 pounds of powder and a shot weighing 183 pounds. The recoil was not sufficient to cause the pawl to catch. A second round was fired with 35 pounds and caused the tongue to break. At the third round with the same charge a tongue which replaced the broken one was also injured. A new tongue was ordered of larger dimensions, and further firing was suspended to await its receipt.

The dimensions of the old and new tongues were as follows:

	Width at neck.	Depth in front of eye.	Thickness of tongue transom.
	Inches.	*Inches.*	*Inches.*
Old tongue	5.	1.8	0.625
New tongue	6.25	3.5	1.125

The details of the changes would be so small on the scale of the drawing sent this day and referred to below that they have been omitted, as it is supposed that if the changes recommended hereafter are made, drawings of details on a larger scale will be required from the Board.

After the reception of the new tongue five rounds were fired without any injury, and the carriage appeared to work very well. The carriage, as at first altered, would only allow 5° of elevation, and as 7° is prescribed the elevating gear was moved backward and downward, while the diameter of the axle connecting the pinions which bear upon the elevating arcs was reduced 0.5 inch. The drawing for the carriage has been modified to conform to these changes, and is returned this day, in connection with Ordnance Office file No. 5675 of 1882. The firing record referred to is forwarded with this report.

It is recommended that alterations made hereafter to fit the casemate carriages for 8-inch rifle guns be made in conformity with the drawing forwarded this day. Whenever practicable, 8-inch rifles will be fired from this carriage in future operations at Sandy Hook.

GEO. W. McKEE,
Major of Ordnance, senior member present.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 8-inch muzzle-loading rifle No. 8 breech

[Gun mounted on 8-inch hydraulic carriage

	Number of fire.	Time.	Powder.		Projectile.		
			Kind.	Weight.	Kind.	Weight.	Elevation.
		1883.		*Lbs.*		*Lbs.*	° '
A. M.—Barometer, 29.877; thermometer, 76; humidity, 64; wind, 6 miles an hour.	3	June 8	Du Pont's hexagonal, E. V. J. Density, 1.750; granulation, 72.	25	Butler (resaboted)	183	......
	4	June 8	......do	35	Butler (new)......	181	.....
P. M.—Barometer, 29.868; thermometer, 85; humidity, 42; wind, 18 miles an hour.	5	June 8	......do	35	....do	181	......
P. M.—Barometer, 29.934; thermometer, 84; humidity, 61; wind, 8 miles an hour.	6	July 16	Du Pont's hexagonal, E. V. M. Density, 1.750; granulation, 72.	35	....do	181	......
	7	July 16	......do	35	....do	181	......
	8	July 16	......do	35	....do	181	......
A. M.—Barometer, 29.969; thermometer, 83; humidity, 72; wind, 20 miles an hour.	9	July 17	......do	35	... do	181	4 30
	10	July 17	......do	35	....do	181	4 30

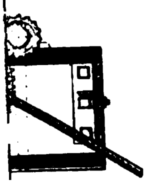
insertion, at Sandy Hook, N. J., from June 8 *to July* 17, 1883.

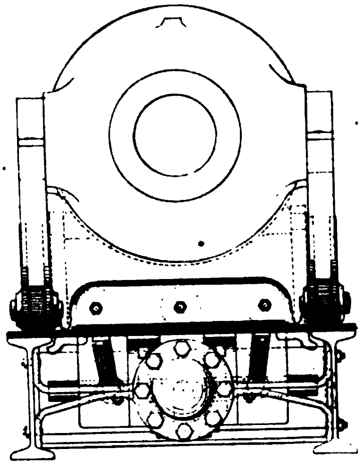
(casemate) altered from 10-inch].

Pressure per square inch of bore.	Instrumental velocity 109 feet from muzzle.	Recoil.	Wind, strength and direction.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.		
Lbs.	*Feet.*	*Feet.*		*Feet.*			
27,000	1,245	3.00	From rear and right 86°, 6 miles an hour.	......	Fired into sand butt to try carriage.		Before firing round 3, fourteen gallons of oil put in cylinder. Did not catch in rack.
38,000	1,424	4.00		......			Caught in second tooth of rack. Pintle tongue broke at eye; gun and carriage thrown about 4 feet to rear.
38,500	......	3.67	From rear and right 86°, 13 miles an hour.	1.17			Before firing round 5, one gallon of oil taken from cylinder Before firing this round new pintle tongue put in. Upper ends of bolts fastening pintle plate to platform bent in this round.
29,500	......	3.92	From rear and right 13°, 8 miles an hour.	......		Carriage did not run in battery after being released from rack until thrown in gear and worked.	Before firing round 6, new tongue attached to carriage. After round 6, one gallon of oil drawn from cylinder. Caught in fifth tooth of rack.
30,000	......	4.33		......			Caught in sixth tooth of rack. After round 7, one gallon of oil drawn from cylinder.
28,000	......	4.67		......			Caught in tenth tooth of rack.
29,000	......	4.67	From front and left 13°, 20 miles an hour.	......	Fired down beach to try carriage.		Caught in tenth tooth of rack.
29,000	......	4.67		......			Before round 10, guides taken off and eased. Caught in tenth tooth of rack.

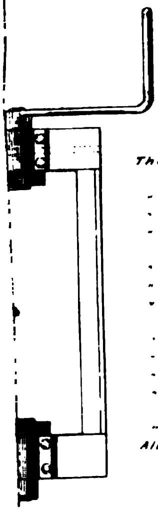
PLATE 1.

RATIONS





FRONT VIEW



MATERIALS

The Front Truck Wheel Plates and Rear Truck Wheel U's (Upper Carriage) " Cylinder Stuffing Box " Rear Truck Wheel Sockets " Elevating Trunnions	are made of Bronze
" Elevating Arc, Gears & Worm " Truck Wheels (Upper Carriage) " Retraction Rope	are made of Steel
" Retraction Gears and Drum " Hand Wheel of Elevating Apparatus " Hydraulic Cylinder " " " Heads	are made of Cast Iron

" Front and Rear Buffers are of Rubber
All other parts are of Wrought-iron

Appendix 34—1883.

U. S. Ordnance Board
Governors Island December 18th 1882.
Altered August 28th 1883.

APPENDIX 35.

REPORT OF FIRING A 15-INCH SMOOTH-BORE GUN WITH INCREASED CHARGES ON A MODIFIED BARBETTE CARRIAGE.

(1 plate.)

JULY 30, 1883.

The ORDNANCE BOARD, U. S. A.,
New York Arsenal:

GENTLEMEN: Referring to my instructions of the 6th instant relative to the early trial of the carriage altered for the 11-inch rifle, it would be well, if the 15-inch smooth-bore gun will fit it, to mount this gun upon the carriage and fire it with 125 pounds charge, and thus ascertain directly the working of the carriage under these charges.

As early action as practicable is desired in this matter as regards both the 11-inch rifle and the 15-inch smooth-bore gun, in order that the Department may not be unnecessarily delayed in taking in hand the alteration of carriages for these guns.

Respectfully, your obedient servant,

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

The Chief of Ordnance, in a letter dated July 30, 1883, ordered that if a 15-inch smooth-bore would fit the carriage altered for the 11-inch rifle, the 15-inch gun should be mounted upon the carriage and fired with 125-pound charges.

The carriage was tried with the 11-inch gun, as shown in Ordnance Board Report No. 10, forwarded with firing records August 6, 1883. By surrounding the trunnions of a 15-inch smooth-bore gun with rings of suitable diameter, it was fitted to this carriage.

The firing began August 22, 1883, with a charge of 125 pounds of E. V. M. powder, and a solid shot weighing 450 pounds. The pressure was 17,500 pounds; and, as there were no unconsumed particles of powder, it was directed that a charge of 130 pounds should be fired at the second round. The pressure in this round was only 20,500 pounds, but small fragments of unburned powder were found in the vicinity of the gun after firing; and it was directed that 130 pounds should be the maximum charge for the rest of the trial. A trial of chilled cast iron and steel shot fired with reduced charges was then carried on, which trial will form the subject of another report, and is only mentioned here to show that a second round of 130 pounds of powder, with a shot weighing 452 pounds, was fired under a depression of 10 feet without any injury to the carriage.

On Friday, August 24, Maj. F. H. Parker, commanding Watertown Arsenal, arrived to witness further firing; and it was directed that two rounds, with 130-pound charges, should be fired at each of the following elevations, viz, 5°, 10°, 15°, and 20°.

This programme was carried out, and an examination of the carriage during and after each round showed that it worked easily and smoothly, and showed no deterioration in any respect moving from and into battery as well when fired under 20° as when lower elevations were used.

These carriages, with rail 27½ inches in depth, will be the same for the 15-inch smooth-bore and 11-inch rifle, except that for the latter the trunnion beds are cut differently and an elevating arc is used to overcome counter-preponderance.

It is recommended that the charge for the 15-inch smooth-bore be made 130 pounds of E. V. powder, having a granulation of 72 and 1.750 density, while the pressure, as shown by firing proof of the powder with a 450-pound solid shot, shall not exceed 25,000 pounds.

The carriage from which the firing with the 15-inch gun took place has, since its alteration, endured 19 rounds, as follows:

Gun.	Number of rounds.	Weight of charge pounds.	Weight of projectile pounds.	Mean pressure, pounds, per square inch.	Remarks.
11-inch M.L. rifle	4	120	548	29, 000	
15-inch Rodman smooth-bore	1	80	453	8, 500	Reduced charges for pla firing.
	1	81	453	8, 000	
	1	81	482	8, 000	
	1	82. 25	452	10, 500	
	1	125	450	17, 500	
	1	130	457	20, 000	
	9	130	452	20, 700	
Total from carriage	19				

It is, of course, not improbable that further firing might develop points of weakness in this altered carriage, but it is supposed that the main elements of the structure have been heretofore thoroughly tested, and except the heavy bolster of wrought iron, which has been substituted for the cast iron one previously used, the parts added do not endure direct strain at the instant of firing. The additional parts are only called into play when recoil has commenced. But to ascertain their endurance, further firing should be carried on, which will also determine the new ranges obtained with the 130-pound charges and serve for the preparation of range tables. It is recommended, therefore, that 100 rounds be fired with elevations varying from 1° to 20°, and for this purpose a request has been made this day for 200 barrels of E. V. M. powder.

GEO. W. McKEE,
Major of Ordnance, senior member present.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 15-*inch Rodman smooth-bore gun, at*

[Gun mounted on 11-inch hydra

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore.
			Kind.	Weight.	Kind.	Weight.		
		1883.		*Lbs. ozs.*		*Lbs.*	° ′	*Lbs.*
A. M.—Barometer, 30.069; thermometer, 83; humidity, 58; wind, 15 miles an hour.	59	Aug. 22	DuPont's hexagonal E. V. M. Density, 1.750; granulation, 72.	125 0	Round shot (new).	450	— 0 1¼	17,5
	60	Aug. 22	......do	130 0	....do	452	— 0 1¼	20,5
	61	Aug. 22	......do	80 0	....do	453	0 0¼	8,5
P. M.	62	Aug. 22	......do	82 4	....do	452	— 0 10	10,5
A. M.—Barometer, 29.996; thermometer, 86; humidity, 68; wind, 12 miles an hour.	63	Aug. 23	......do	81 0	Round shot, steel (new).	482	— 0 10	8,
P. M.—Barometer, 29.912; thermometer, 91; humidity, 66; wind, 12 miles an hour.	64	Aug. 23	......do	81 0	Round shot, iron (chilled).	453	— 0 10	8,0
	65	Aug. 23	......do	130 0	....do	457	— 0 15	20,00
P. M.—Barometer, 29.946; thermometer, 80; humidity, 54; wind, 13 miles an hour.	66	Aug. 24	......do	130 0	Round shot (old).	458	5 00	20,00
	67	Aug. 24	......do	130 0	....do	453	5 00	21,2
	68	Aug. 24	......do	130 0	....do	455	10 00	20,4
	69	Aug. 24	......do	130 0	....do	455	10 00	20,4
	70	Aug. 24	......do	130 0	....do	455	15 00	20,4
	71	Aug. 24	......do	130 0	....do	454	15 00	26,0
	72	Aug. 24	......do	130 0	....do	455	20 00	17,0
	73	Aug. 24	......do	130 0	....do	454	20 00	19,0

Sandy Hook, N. J., from August 22 to August 24, 1883.

carriage, altered from a 15-inch carriage.]

Instrumental velocity, 108 feet from muzzle.	Recoil.	Wind, strength and direction.	Ranges.	Deflection, left.	Time of flight.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
Feet.	*Feet.*		*Yds.*	*Yds.*	"		
1, 613	6. 17	From front and left 17°, 15 miles an hour.	......	...	......	Fired into sand butt.	At round 59, dog which catches in rack to prevent carriage running in battery was broken, and pieces were removed, and carriage allowed to run in battery during the remaining rounds.
1, 658	6. 25	....do	......	...	......		
1, 288	5. 67	....do	......	...	......	Fired at 200-yard target.	
1, 345	5. 62	....do	......	...	......		
1, 259	5. 46	From front and right 38°, 12 miles an hour.	......	...	......	Fired at 200-yard iron target (normal).	Shot cracked—found 9′ 4″ from target. Right-hand side of target thrown back 12⅛″ and to right 11⅜″. Penetration, 19″.25. (See plates.)
1, 288	5. 50	From front and right 2°, 12 miles an hour.	......	...	......		Shot broken into small fragments, the greater part of which remained in the target. Right-hand side of target thrown back 9⅜″ and left-hand side 9″, and entire target thrown to left 11″. Penetration, 31″.25. (See plates.)
1, 635	6. 25	....do	......	...	......		Gun washed out, examined, and star-gauged. Shot passed through target and found lodged between the 1″ rear plate of target and one of the rear braces. Right side of target thrown back 2′ 2″, and entire target thrown 16″ to right. (See plates.)
1, 696	6. 08	From rear and right 39°, 13 miles an hour.	2, 909	31	Lost.	Fired out to sea for range.	
1, 709	6. 20	... do	3, 040	37	7. 85		
......	6. 17	....do	4, 429	21	14. 75		
......	6. 12	....do	4, 393	32	13. 5		
......	6. 04	....do	5, 478	15	Lost.		
......	6. 08	....do	5, 498	20	19. 50		Gun washed out, examined with mirror, and star-gauged.
......	6. 07	....do	6, 182	14	25. 25		
......	6. 14	....do	6, 265	49	24. 50		

FIRING OF 100 ROUNDS WITH 130 POUNDS OF POWDER FROM A 15-INCH RODMAN SMOOTH-BORE GUN, MOUNTED ON AN ALTERED BARBETTE CARRIAGE INCREASED IN HEIGHT.

This firing was directed by the Chief of Ordnance, in a letter dated August 31, 1883.

The gun was the 15-inch Rodman smooth-bore, No. 114.

The powder was of the E. V. M. type; granulation, 72 grains to the pound; density, 1.750.

The projectiles were cast-iron solid shot, weighing from 452 to 458 pounds.

The carriage, increased in height for the 15-inch gun, is a front pintle barbette carriage altered and strengthened. The chassis consists of two rails, 27.5 inches deep, each composed of two plates of boiler-iron, the top and bottom surfaces being formed by the flanges of T-bars, the web of the latter passing between the edges of the plates. Short channel bars, perpendicular to the edges of the chassis rails, are bolted at intervals to the exterior, and add strength and stiffness. Between the rails lies a cast-iron hydraulic cylinder, supported by transoms bent to a circular form, and accurately bored to fit corresponding turned surfaces on the cylinder. These transoms are bolted to the chassis rails. The cylinder contains a loose-fitting piston-head, perforated with four holes, circular in cross-section, their longitudinal section being that of two conic frustra joined at their smaller bases. The piston-rod passes through a stuffing-box in the rear cylinder-head, and, passing also through an elongated slot in the cross-head of the gun-carriage, terminates in an eye. A pin inserted through the eye bears rollers, which rest against the rear face of the cross-head when the piece is recoiling. In rear of the hydraulic cylinder are three cross-transoms, between which diagonal braces are situated. A flat transom is fastened to the top of the rails in front, and bears a plate, to which four rubber buffers are attached, to prevent severe shock when the gun runs in battery. A similar device is found near the rear of the chassis. On the upper surfaces of the chassis rails wedge-shaped bars of wrought iron are bolted, upon which the rear truck wheels of the gun-carriage rise during recoil. To draw the carriage from battery, an axle bearing a drum and actuated by bevel gearing is placed at the rear of the chassis. Heavy wrought-iron bolsters are bolted to lower face of the chassis in front. These bolsters are bolted below to the pintle transom and rest upon four conical steel rollers. Near the middle of the chassis are wrought-iron props, through which pass screws intended to rest upon the middle traverse circle. By raising or lowering these screws the bearing can be accurately adjusted, and settling of the platform may to some extent be compensated for. Before firing, these screws should be brought to a light bearing by turning them down until they touch the rail and then reversing the motion by one-half a turn. The forks rest upon the rear traverse wheels, which have holes in their periphery for the insertion of maneuvring hand-spikes. Hooks for the hand-spikes, bars, and steps, are suitably attached.

The gun-carriage has two cheeks, connected by four transoms, one of which is placed almost vertically below the trunnion-beds. The other three transoms connect the lower part of the cheeks; the front one bears guide-hooks to prevent lateral movement of the carriage, and bears also a plate to strike against the front rubber buffers; the middle one forms a support for braces connected with the cross-head; the rear one bears guide-hooks and the heavy cross-head which connects the piston-rod of the hydraulic cylinder to the gun-carriage. Each cheek is composed of two triangular plates of boiler-iron, separated by radial struts of flat bar-iron so arranged as to aid in resisting the weight of the gun and the shocks due to recoil. Between the edges of the plates the web part of a T-bar is inserted, the flanged part overlying the cheeks and adding stiffness in front and rear, while at the bottom the flange acts as a shoe upon which the carriage rests when in battery. To the front and lower angle of each cheek heavy bronze castings are bolted, which are embossed and bored to form boxes for the concentric journals of the front truck-wheels. Similar bronze castings in the rear receive an eccentric axle, to which two steel truck-wheels are attached. When it is necessary to draw back the gun before firing, the eccentric axle is thrown into gear by means of hand-spikes inserted into the bronze sockets at the extremities of the axle. The shoe is cut away in the vicinity of the front truck-wheels to allow them to bear lightly on the chassis rails when the gun is in battery. When the carriage recoils the rear wheels ascend the wedge-shaped rails of the chassis, the front wheels bear firmly, and the carriage recedes with rolling friction. The rising of the rear of the carriage would tend to bend the piston-rod if it were rigidly connected with the cross-head, but the elongated slot in the latter and the rollers at the end of the rod overcome this tendency. A spring pawl is attached to the left side of the gun-carriage and engages in the teeth of a rack fastened to the chassis rail, thus retaining the carriage at the point it may reach in recoiling. This arrangement, devised by Mr. A. G. Sinclair, is considered greatly superior to the spring clamps heretofore used for this purpose.

When the gun is to be run into battery the pawl is raised by a short but powerful cam lever; the carriage then moves forward, and when the rear wheels have passed from the wedge rails the carriage rests upon the shoe and moves for a short distance on sliding friction. The forward movement diminishes gradually under these circumstances and finally ceases when the plate bolted for the purpose to the front lower transom strikes the rubber buffers. The trunnion-beds are made by bending a T-bar into the proper shape. The upper surface of the flange forms the bed, and the web inserted between the cheek-plates is bolted to them. To the rear transom a wrought-iron ratchet post is bolted to provide a fulcrum for the elevating bar by which the piece is given elevation or depression. Steps are affixed to either side of the post for the convenience of the gunner in pointing, and two steps are attached to each cheek. A crane attached to the right cheek supports a differential pulley by which the shot is raised.

The carriage for the 11-inch rifle will resemble the one above described in every respect except that the trunnion bed-plates will be formed to receive an eccentric trunnion-ring designed to overcome counter preponderance, and the ratchet post and bar will be replaced by an elevating arc and gears. The bronze elevating arc is connected to the piece by bronze trunnions, and is in form a circular-toothed rack actuated by a triple gear. Two hand-wheels are required to work the gearing, and when the proper elevation is obtained these wheels are locked in their place friction-tight by a locking nut with long arms. The inertia of the gun tends to keep the axis in the same position when the rear of the carriage rises on the wedge-rails during recoil, and if the piece were connected through some unyielding medium with the carriage the latter or some of its parts would be unduly strained. The friction-clamp above referred to allows the system to yield to the inertia of the gun while it secures stability in the degree of elevation given before firing—a condition that, owing to the loose fit of the gear-teeth, did not exist before the clamp was applied.

The carriage, not increased in height for either the 15-inch Rodman smooth-bore gun or the 11-inch rifle, will resemble those above described in all details except that the chassis rails are but 20 inches deep and between their lower faces and the upper faces of the bolster, props, and forks will be inserted beams 7.5 inches in depth and built up after the fashion of the chassis rails.

The trial of the 15-inch Rodman smooth-bore began September 18, 1883, the gun being mounted for the purpose upon a carriage increased in height and arranged for the 11-inch muzzle-loading rifle. To fit the 15-inch gun to the trunnion-beds of the carriage, rings were shrunk upon the trunnions which gave to them the proper diameter. Ten series of ten rounds each with charges of 130 pounds of E. V. powder were fired at elevations of 2°, 4°, 6°, 8°, 10°, 12°, 14°, 16°, 18°, and 20°. At the fourth round of the first series (round 77 of the record), the left front guide-hook was broken and two slight depressions were observed on the upper surfaces of the chassis rails where the front truck-wheels bear.

In the seventh round of the series, at 8° elevation (round 110 of the record), a bolt connecting the trunnion of the left-hand elevating arc to the piece broke.

Before the firing under 18° elevation, a cast-iron ratchet post was substituted for the elevating arc, but soon broke, as did four others substituted for it successively in subsequent rounds. The depression of the chassis rails, previously adverted to, increases gradually during the firing. The length of the depression on the left-hand rail was about 9.5 inches, and its maximum depth was about 0.187 inch. The depression in the right-hand rail was of the same length but not quite so deep.

Three bolts in the rear transom were broken during the firing at different times, due to the springing of the transom, which is too light.

Ranges were determined at the different elevations, and are given in the table below.

The carriage was scrutinized carefully during firing, and the following defects are noted and remedies suggested:

1st. The upper surfaces of the chassis rails were deflected. The truck-wheels, which are now inside the web portion of the rail, should be placed in the center of the rail.

2d. The cross-head transom, 1 inch thick, showed weakness, and should be increased to 1¼ inches.

3d. The cross-head, 2½ inches thick, was slightly "sprung" in firing and should be 3 inches thick, and at the lower edge about 6 inches longer. The slot in the cross-head through which the piston-rod passes is deeper than is necessary, and its depth should be diminished by 1½ inches.

4th. The front and rear guide-hooks are not strong enough, and should be 8 inches wide by 1¼ inches thick, instead of 6 inches by 1 inch, as now made. The guide-hook bolts should be 1¼ inches instead of 1 inch.

5th. To increase the stiffness of the chassis, an upright transom, 10 or 12 inches wide by ⅝-inch thick, should be bolted to the forks of the maneuvering wheels, and a similar one to the props.

6th. The transoms which hold the hydraulic cylinder are forged with too rapid a curve at their re-entrant angles, and curves of 1 inch radius should be substituted, and the arms of these transoms, instead of being curved gradually to their points of support on the chassis rails, should be carried out straight.

7th. The retraction gear, consisting of an axle rotated by worm and bevel gearing is not satisfactory, and should be replaced by an axle actuated by a spring pawl and levers, as used in the garrison gin and applied to the 20-inch gun-carriage at Fort Hamilton.

8th. The position of the crane on the carriage is inconvenient, and it is recommended that hereafter it shall be attached to the chassis.

Range table.

Elevation.	Number of rounds.	Mean weight of projectile.	Mean initial velocity.	Mean range.	Mean error.		25 per cent. probable rectangle.		Remarks.
					Range.	Deflection.	Length.	Breadth.	
Degrees.		*Pounds*	*F. S.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	
2	10	455.0	1,706	1,598	25.9	3.8	44	6.4	
4	10	454.5	1,693	2,505	65.4	3.11	111	5.0	
6	8	455.0	1,713	3,267	74.0	3.22	125	5.4	
8	10	455.0	1,706	3,878	49.0	10.7	83	18.0	
10	10			4,490	35.6	14.7	60	25.0	
12	7			4,758	23.4	15.6	40	26.4	
14	8			5,161	22.0	21.9	37	37.0	
16	10			5,505	22.9	10.5	39	17.7	Over water.
18	10			5,954	51.3	18.3	87	31.0	
20	9			6,421	52.5	21.1	89	35.7	

The total number of rounds fired in determining the table was 119, some of which were rejected from the calculation as abnormal.

In addition to the above, the following rounds have been fired from this carriage:

Gun.	Number of rounds.	Weight of charge.	Weight of projectile.	Mean pressure per sq. inch.	Remarks.
		Pounds.	*Pounds.*	*Pounds.*	
11-inch M. L. rifle	4	120.00	548	29,000	
15-inch Rodman smooth-bore.	1	80.00	453	8,500	Reduced charges for plate firing.
	1	81.00	453	8,800	
	1	81.00	482	8,000	
	1	82.25	452	10,500	
	1	125.00	450	17,500	
	1	130.00	457	20,000	
	9	130.00	452	20,700	
Total	19				

The total number of rounds fired up to the present time is 119.

In conclusion, the Board would report that the carriage has worked smoothly and well. When the changes recommended are made, the carriage will be strong enough to endure the firing of the 15-inch Rodman smooth-bore gun with charges of 130 pounds of powder.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 15-*inch Rodman smooth-bore gun,* No. 114.

[Gun mounted on 15-inch barbette carriage.

	Number of fire.	Time.	Powder.		Projectile.		Elevation in degrees.	Pressure per square inch of bore.	Instrumental velocity 112 feet 7 inches from muzzle.	[illegible]
			Kind.	Weight.	Kind.	Weight.				
		1883.		*Lbs.*		*Lbs.*		*Lbs.*	*Feet.*	[illegible]
Barometer, 30.030; thermometer, 70; humidity, 62.	74	Sept. 18	Du Pont's hexagonal E. V. M. Density, 1.750; granulation, 72.	130	Round iron solid shot.	455	2	21,400	1,679	[illegible]
	75	Sept. 18		130		455	2	24,500	1,708	[illegible]
	76	Sept. 18		130		455	2	21,400	1,679	[illegible]
Barometer, 30.350; thermometer, 65.5; humidity, 65.	77	Sept. 19		130		455	2	21,900	1,677	[illegible]
	78	Sept. 19		130		455	2	25,000	1,686	[illegible]
Barometer, 30.203; thermometer, 65; humidity, 73.	79	Sept. 20		130		455	2	21,000	1,664	[illegible]
	80	Sept. 20		130		455	2	21,700	1,705	[illegible]
	81	Sept. 20		130		455	2	25,700	1,700	[illegible]
	82	Sept. 20		139		456	2	24,400	1,663	[illegible]
	83	Sept. 20		130		456	2	25,600	1,706	[illegible]
Barometer, 29.982; thermometer, 64; humidity, 84.	84	Sept. 21		130		455	4	21,600	1,680	[illegible]
	85	Sept. 21		130		456	4	22,900	1,667	[illegible]
	86	Sept. 21		130		456	4	22,200	1,679	[illegible]
	87	Sept. 21		130		454	4	....	1,692	[illegible]
	88	Sept. 21		130		454	4	22,000	1,667	[illegible]
Barometer, 29.990; thermometer. 69; humidity, 78.	89	Sept. 21		130		454	4	....	1,676	[illegible]
	90	Sept. 21		130		454	4	....	1,688	[illegible]
	91	Sept. 21		130		454	4	....	1,661	[illegible]
	92	Sept. 21		130		454	4	....	1,683	[illegible]
	93	Sept. 21		130		454	4	25,300	1,686	[illegible]

***at Sandy Hook, N. J., from September* 18 *to October* 4, 1883.**

increased in height for the 11-inch M. L. rifle.]

Wind, strength, and direction.	Range.	Deflection.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
		Right.	Left.		
	Yds.	*Yds.*	*Yds.*		
From front and left 32°, 15 miles an hour.	1, 633	......	3. 00	Fired down beach to obtain ranges and try carriage. In rounds 74 to 93, inclusive, top carriage was caught and held by rack, except in round 79, when guide broke; carriage ran in when released from rack very satisfactorily. Before firing round 79 some repairs had to be made to platform, so as to bring gun level.	Before firing round 74, traverse circle lowered 1″, and consequently rear end of carriage. Gun examined and star-gauged.
	1, 555	0. 05	......		Before firing round 75, 1 gallon of oil added to cylinder, making 24 gallons.
	1, 603	1. 66	......		
From rear and left 60°, 11 miles an hour.	1, 574	......	1. 16		At round 77: Left guide broken and top carriage thrown to left, resting on rack; guide replaced and heavier bolts used to hold it. Right bolt of rear transom of top carriage broken and depression observed in chassis rails where rollers commence to bear. Right hand rear transom bolt broken; replaced before firing again.
	1, 564	2. 00	......		
From left and front 77°, 6 miles an hour.	1, 569	......	0. 66		Before firing round 79, 1 gallon of oil added to cylinder, making 25 gallons.
	1, 643	2. 33	......		
	1, 605	1. 66	......		Gun washed out, examined, and star-gauged.
	1, 598	....	2. 16		
	1, 635	3. 50	......		
From left and front 77°, 10 miles an hour.	2, 602	Lost.	Lost.		Left hand rear transom bolt broken; replaced before firing again.
	2, 402	0	0		
	2, 548	1. 00	......		
	2, 421	1. 66	......		
	2, 538	5. 83	......		
From left and front 77°, 8 miles an hour.	2, 554	7. 50	......		
	2, 508	0	0		
	2, 502	7. 16	......		
	2, 366	0. 66	......		
	2, 605	......	4. 33		

Record of firing with 15-inch Rodman smooth-bore gun, No. 114, at Sandy

	Number of fire.	Time.	Powder.		Projectile.		Elevation in degrees.	Pressure per square inch of bore.	Instrumental velocity 112 feet 7 inches from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
		1883.		*Lbs.*		*Lbs.*		*Lbs.*	*Feet.*	*Feet*
Barometer, 30.100; thermometer, 52; humidity, 67.	94	Sept. 26	Du Pont's hexagonal E. V. M. Density, 1.750; granulation, 72.	130	Round iron solid shot.	455	6	23, 900	1, 685	5.
	95	Sept. 26		130		455	6	--------	1, 707	5.8
	96	Sept. 26		130		455	6	--------	1, 692	5.9
	97	Sept. 26		130		455	6	--------	1, 680	5.
	98	Sept. 26		130		455	6	--------	1, 719	5.
	99	Sept. 26		130		455	6	25, 000	1, 701	5.9
	100	Sept. 26		130		455	6	--------	1, 685	5.
	101	Sept. 26		130		455	6	--------	1, 701	5.
	102	Sept. 26		130		455	6	--------	1, 679	5.9
	103	Sept. 26		130		455	6	--------	1, 693	5.
Barometer, 30.118; thermometer, 68; humidity, 85.	104	Sept. 26		130		455	8	24, 900	--------	5.9
	105	Sept. 26		130		455	8	--------	--------	5.
	106	Sept. 26		130		455	8	--------	--------	5.
	107	Sept. 26		130		455	8	--------	--------	5.
	108	Sept. 26		130		455	8	--------	--------	5.
	109	Sept 26		130		455	8	24, 100	--------	5.
	110	Sept. 26		130		455	8	--------	--------	5.
	111	Sept. 26		130		455	8	--------	--------	6.
	112	Sept. 26		130		455	8	--------	--------	5.
	113	Sept. 26		130		455	8	--------	--------	5.81

Hook, N. J., from September 18 *to October* 4, 1883—Continued.

Wind, strength, and direction.	Range.	Deflection.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
		Right.	Left.	
	Yds.	*Yds.*	*Yds.*	
From rear and right 40°, 15 miles an hour.	3, 209	Lost.	Lost.	Fired down beach to obtain ranges and try carriage.
	3, 160	Lost.	Lost.	
	Lost.	Lost.	Lost.	
	Lost.	Lost.	Lost.	
	3, 431	......	17. 66	
	3, 333	......	20. 33	
	3, 296	......	25. 66	
	3, 285	......	13. 66	
	3, 134	......	13. 66	
	3, 286	.....	18. 00	
From rear and right 39°, 12 miles an hour.	3, 841	......	0. 33	
	3, 862	......	44. 33	
	3, 914	......	42. 00	
	3, 855	......	36. 00	
	3, 964	......	40. 00	
	3, 805	......	19. 33	
	3, 807	......	30. 00	Elevating trunnion bolt broke.
	3, 852	......	30. 33	
	3, 945	......	16. 66	
	3, 933	......	23. 00	Gun washed out, examined, star-gauged, and impressions taken of vent.

Record of firing with 15-*inch Rodman smooth-bore gun, No.* 114, *at S*

	Number of fire.	Time.	Powder.		Projectile.		Elevation in degrees.	Pressure per square inch of bore.	Recoil
			Kind.	Weight.	Kind.	Weight.			
		1883.		*Lbs.*		*Lbs.*		*Lbs.*	*Ft.*
Barometer, 30.213; thermometer, 62; humidity, 56.	114	Sept. 27	Du Pont's hexagonal E. V. M. Density, 1.750; granulation, 72.	130	Round iron solid shot.	455	10	21, 900	5.
	115	Sept. 27		130		455	10	....	5.
	116	Sept. 27		130		455	10	....	5.
	117	Sept. 27		130		455	10	....	5.
	118	Sept. 27		130		455	10	....	5.
	119	Sept. 27		130		455	10	23, 300	5
	120	Sept. 27		130		456	10	....	5
	121	Sept. 27		130		456	10	....	5
	122	Sept. 27		130		456	10	....	5
	123	Sept. 27		130		456	10	....	5.
Barometer, 29.953; thermometer, 62; humidity, 50.	124	Oct. 1		130		456	16	22, 900	5.
	125	Oct. 1		130		456	16	....	5.
	126	Oct. 1		130		456	16	....	5.
	127	Oct. 1		130		456	16	....	5.
	128	Oct. 1		130		456	16	....	5
	129	Oct. 1		130		456	16	25, 400	5.
	130	Oct. 1		130		456	16	....	5.
	131	Oct. 1		130		456	16	....	5.
	132	Oct. 1		130		456	16	....	5.
	133	Oct. 1		130		456	16	....	5.

Hook, N. J., from September 18 *to October* 4, 1883—Continued.

Wind, strength, and direction.	Range.	Deflection.		Time of flight.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
		Right.	Left.		
	Yds.	*Yds.*	*Yds.*	*Secs.*	
From front and right 52°, 17 miles an hour.	4, 218	......	63. 00	.....	Fired down beach to obtain ranges and try carriage. Slots cut in transom to allow elevating racks to pass through.
	4, 276	......	21. 33	.....	
	4, 252	......	55. 66	.....	
	4, 305	......	42. 66	.....	
	4, 245	......	37. 66	13¼	
	4, 279	......	35. 33	14	
	4, 331	......	76. 66	13¾	
	4, 298	......	61. 00	13¾	
	4, 363	......	52. 66	14	
	4, 329	......	80. 33	13¾	
From rear and left 88°, 3-7 miles an hour.	5, 490	......	25. 00	.....	Fired to sea for ranges and to try carriage. Gun washed out, examined, star-gauged, and impressions taken of vent.
	5, 462	......	4. 50	19¾	
	5, 476	......	1. 00	19¼	
	5, 496	......	6. 00	20	
	5, 509	......	2. 00	19¾	
	5, 513	7. 00	......	19¾	
	5, 545	0	0	20	
	5, 528	24. 00	......	19½	
	5, 487	......	41. 00	20	
	5, 545	0	0	20¼	

Record of firing with 15-inch Rodman smooth-bore gun, No. 114, at Sandy

	Number of fire.	Time.	Powder.		Projectile.		Elevation in degrees.	Pressure per square inch of bore.	Recoil.
			Kind.	Weight.	Kind.	Weight.			
		1883.		*Lbs.*		*Lbs.*		*Lbs.*	*Feet.*
Barometer, 30.036; thermometer, 58; humidity, 58.	134	Oct. 8	Du Pont's hexagonal E. V. M. Density, 1.750; granulation, 72.	130	Round iron solid shot.	454	18	23,100	5.91
	135	Oct. 8		130		454	18	....	5.83
	136	Oct. 3		130		454	18	....	5.91
	137	Oct. 8		130		454	18	....	5.91
	138	Oct. 3		130		454	18	....	5.91
	139	Oct. 8		130		454	18	25,200	5.91
	140	Oct. 8		130		454	18	....	5.91
	141	Oct. 3		130		454	18	....	5.91
	142	Oct. 3		130		454	18	....	5.91
	143	Oct. 8		130		454	18	....	5.91
Barometer, 29.975; thermometer, 66; humidity, 48.	144	Oct. 3		130		456	20	24,500	5.91
	145	Oct. 8		130		456	20	....	5.91
	146	Oct. 8		130		456	20	....	5.83
	147	Oct. 8		130		456	20	....	5.83
	148	Oct. 3		130		456	20	....	5.83
	149	Oct. 8		130		456	20	22,800	5.83
	150	Oct. 8		130		456	20	....	5.91
	151	Oct. 8		130		456	20	....	5.91
	152	Oct. 8		130		456	20	....	5.91
	153	Oct. 8		130		152	20	....	5.91

Hook, N. J., from September 18 *to October* 4, 1883—Continued.

Wind, strength, and direction.	Range.	Deflection.		Time of flight.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
		Right.	Left.			
	Yds.	*Yds.*	*Yds.*	*Secs.*		
From rear and right 58°, 11–13 miles an hour.	5,900	......	59.50	21¼	Fired to see for ranges and to try carriage.	Elevating-racks removed and elevating-post substituted.
	6,093	......	72.00	21¾		
	5,965	......	33.00	21		
	6,010	......	89.50	22		
	5,837	......	39.50	21½		
	5,951	......	19.00	21¾		Ratchet-post broke and removed during each of the next three rounds after elevation was obtained.
	5,927	......	84.00	21¾		
	5,976	......	85.00	21½		
	5,900	......	59.50	22		Impressions taken of vent; a new ratchet-post put in.
	5,984	......	63.00	22¼		
From front and left 58°, 2–6 miles an hour.	6,532	......	118.00	23¾		
	6,361	......	141.00	23¾		
	6,335	......	88.00	23¼		
	6,350	......	94.00	23¼		
	6,403	......	3.00	23¾		
	6,470	......	64.00	24		
	6,399	......	132.00	23½		Ratchet-post broke, but used during three rounds.
	6.443	......	152.00	23½		
	6,447	......	116.00	24		Gun washed out and examined; elevating racks put back in place.
	6,447	......	116.00	23½		

Record of firing with 15-*inch Rodman smooth-bore gun, No.* 114, *at Sandy*

	Number of fire.	Time.	Powder.		Projectile.		Elevation in degrees.	Pressure per square inch of bore.	Recoil.
			Kind.	Weight.	Kind.	Weight.			
		1883.		*Lbs.*		*Lbs.*		*Lbs.*	*Feet.*
Barometer, 30.288; thermometer, 52; humidity, 59.	154	Oct. 4	Du Pont's hexagonal E. V. M. Density, 1.750; granulation, 72.	130	Round iron solid shot.	458	12	24, 400	6.
	155	Oct. 4		130		458	12	....	6.
	156	Oct. 4		130		458	12	....	6.
	157	Oct. 4		130		458	12	....	6.
	158	Oct. 4		130		457	12	....	6.
	159	Oct. 4		130		457	12	20, 500	6.
	160	Oct. 4		130		457	12	....	6.
	161	Oct. 4		130		457	12	....	6.
	162	Oct. 4		135		457	12	....	6.
	163	Oct. 4		130		457	12	....	6.
	164	Oct. 4		130		454	14	25, 300	6.
	165	Oct. 4		130		454	14	....	6.
Barometer, 30.258; thermometer, 55; humidity, 39.	166	Oct. 4		130		454	14	....	6.
	167	Oct. 4		130		453	14	....	6.
	168	Oct. 4		130		453	14	....	6.
	169	Oct. 4		180		453	14	24, 000	6.
	170	Oct. 4		130		453	14	....	6.
	171	Oct. 4		130		453	14	....	6.
	172	Oct. 4		180		453	14	....	6.
	173	Oct. 4		180		453	14	....	6.

Hook, N. J., from September 18 *to October* 4, 1883—Continued.

Wind, strength, and direction.	Range.	Deflection. Right.	Deflection. Left.	Time of flight.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	Yds.	*Yds.*	*Yds.*	*Secs.*	
From rear and right 40°, 13–18 miles an hour.	Lost.	Lost.	Lost.	Lost.	Fired down beach to obtain ranges and try carriage.
	Lost.	Lost.	Lost.	Lost.	
	Lost.	Lost.	Lost.	Lost.	
	4,735	......	17.00	16	
	4,756	......	45.00	16	
	4,752	......	75.00	16	
	4,820	......	34.00	16	
	4,768	......	11.00	16	
	4,707	......	50.00	16	
	4,768	......	40.00	16	
	Lost.	Lost.	Lost.	18	
	Lost.	Lost.	Lost.	18	
From rear and right 4°, 21–25 miles an hour.	5,140	15.00	....	17½	Fired to sea for ranges and to try carriage.
	5,236	......	27.00	18½	
	5,163	27½	....	17½	
	5,166	......	24.00	18	
	5,163	27½	....	18	
	5,105	29½	....	17½	
	5,163	27½	....	18	
	5,148	62.00	....	17¾	

Table of enlargements of 15-inch Rodman smooth-bore gun, No. 114.

Inches from muzzle.	Original diameter of bore, Dec. 21, 1875.	Enlargements after—									
		17 rounds, Jan. 6, 1876.	36 rounds, Feb. 26, 1876.	44 rounds, Aug. 23, 1876.	65 rounds, Aug. 24, 1883.	71 rounds, Aug. 25, 1883.	73 rounds, Sept. 18, 1883.	83 rounds, Sept. 20, 1883.	118 rounds, Sept. 27, 1883.	138 rounds, Oct. 8, 1883.	179 rounds, Oct. [illegible], 1883.
156	15.004	0.004	0.005	0.005	0.010	0.010	0.009	0.010	0.011	0.011	0.011
155	15.004	.007	.006	.007	.009	.009	.009	.009	.010	.011	[illegible]
154	15.005	.005	.005	.005	.009	.007	.007	.009	.009	.010	[illegible]
153	15.005	.006	.006	.007	.010	.007	.007	.009	.010	.011	[illegible]
152	15.003	.008	.008	.009	.010	.011	.010	.010	.012	.012	.012
151	15.002	.009	.009	.010	.011	.011	.011	.010	.012	.013	.013
150	15.006	.004	.005	.006	.007	.007	.007	.007	.010	.009	.004
149	15.007	.004	.0055	.005	.006	.006	.006	.005	.008	.008	.007
148	15.007	.003	.0055	.005	.005	.007	.005	.005	.008	.009	.007
147	15.007	.004	.005	.005	.006	.005	.005	.005	.009	.009	.007
146	15.008	.003	.0035	.004	.005	.006	.007	.004	.007	.008	[illegible]
145	15.0075	.0045	.0035	.0045	.0045	.0045	.0055	.0055	.0085	.0075	[illegible]
144	15.006	.006	.005	.006	.007	.006	.007	.008	.009	.009	.011
143	15.008	.003	.004	.004	.005	.004	.005	.005	.006	.007	.012
142	15.007	.005	.005	.005	.005	.005	.006	.006	.008	.011	.011
141	15.007	.0055	.005	.005	.005	.005	.007	.006	.007	.014	.015
140	15.003	.009	.0085	.009	.007	.009	.010	.010	.011	.012	.013
139	15.013	—.001	—.001	.003	—.003	—.002	.000	.000	.003	.003	.005
138	15.009	.002	.0025	.003	.001	.001	.004	.004	.007	.010	[illegible]
137	15.009	.0035	.0025	.003	.001	.002	.004	.004	.008	.010	.013
136	15.008	.004	.003	.004	.004	.004	.005	.005	.010	.015	.016
135	15.008	.004	.003	.004	.005	.006	.007	.004	.013	.014	.019
134	15.007	.006	.004	.005	.006	.005	.006	.007	.012	.016	.021
133	15.009	.003	.001	.003	.004	.003	.004	.005	.011	.014	.019
132	15.004	.008	.006	.006	.008	.007	.008	.009	.014	.014	.024
131	15.003	.009	.007	.008	.010	.008	.009	.012	.015	.017	.021
130	14.998	.014	.012	.012	.016	.014	.016	.016	.024	.022	.027
129	15.007	.005	.004	.004	.005	.003	.008	.007	.012	.013	.015
128	15.004	.009	.006	.007	.009	.006	.009	.009	.016	.016	.014
127	15.005	.007	.006	.006	.009	.005	.008	.008	.013	.012	[illegible]
126	15.004	.008	.007	.007	.006	.006	.009	.008	.013	.013	[illegible]
125	15.003	.010	.007	.009	.007	.007	.007	.008	.012	.013	[illegible]
124	15.003	.010	.007	.009	.007	.006	.009	.008	.012	.015	.017
123	15.000	.012	.011	.012	.009	.009	.011	.011	.016	.015	.021
122	15.002	.011	.009	.010	.007	.008	.008	.008	.013	.014	.015
121	14.998	.014	.0125	.013	.011	.011	.011	.011	.016	.018	.019
120	14.999	.014	.012	.012	.009	.010	.011	.009	.015	.017	.016
119	15.004	.008	.007	.007	.006	.005	.005	.005	.010	.012	.014
118	15.000	.012	.010	.011	.008	.009	.009	.008	.014	.015	.015
117	15.010	.002	.0005	.001	.000	—.002	—.001	—.002	.003	.005	.004
116	15.007	.005	.003	.004	.002	.001	.001	.001	.006	.006	.006
115	15.009	.002	.0015	.002	.000	.000	—.001	—.001	.008	.004	.005
114	15.010	.001	.000	.001	—.001	—.002	—.003	—.002	.003	.003	.003
113	15.010	.001	.000	.001	—.001	—.002	—.003	—.002	.002	.001	.003
112	15.010	.001	.000	.001	—.002	—.002	—.003	—.003	.003	.003	.003
111	15.010	.001	.001	.000	—.002	—.002	—.003	—.003	.002	.002	.001
110	15.010	.001	—.001	.000	—.002	—.002	—.003	—.003	.002	.004	.000
109	15.010	.001	—.001	.000	—.002	—.002	—.002	—.003	.001	.001	[illegible]
108	15.010	.001	—.001	—.002	—.002	—.001	—.002	—.003	.001	.001	—.001
107	15.007	.004	.0025	.003	.001	.001	.001	.000	.004	.003	.003
106	15.008	.003	.001	.001	.000	.000	.000	.000	.001	.003	.002
105	15.010	.001	—.001	—.001	—.002	—.002	—.001	—.003	—.001	.000	.000
104	15.007	.004	.002	—.003	.003	.001	.001	.000	.003	.003	.003
103	15.008	.002	.002	.001	.001	.000	.000	—.001	.001	.001	.002
102	15.008	.002	.002	.002	.001	—.001	.000	—.001	.002	.001	.002
101	15.008	.002	.0015	.002	.000	—.001	—.001	—.001	.002	.001	.002
100	15.010	.001	—.0005	—.001	—.003	—.003	—.003	—.003	.000	.000	.000
98	15.011	.000	—.0015	—.002	—.003	—.003	—.004	—.004	—.001	—.002	—.002
96	15.010	.001	.000	—.001	—.002	—.001	—.002	—.003	—.001	—.001	—.001
94	15.010	.001	.000	.000	—.002	—.002	—.002	—.003	—.002	—.001	—.001
92	15.010	.001	.0005	.000	—.002	—.002	—.002	—.003	—.002	.000	—.001
90	15.010	.002	.000	.001	—.002	—.001	—.003	—.003	—.001	.000	—.001
88	15.010	.002	.000	.001	—.002	—.002	—.003	—.003	—.001	.000	—.001
86	15.010	.002	.0005	.001	—.002	—.002	—.002	—.003	—.001	.000	.000
84	15.010	.001	.0005	.001	—.002	—.002	—.002	—.003	—.001	.000	.000
82	15.010	.001	.0005	.001	—.002	—.002	—.002	—.002	.000	.000	.000
80	15.011	.002	.000	.000	—.003	—.003	—.003	—.003	—.001	—.001	—.001
78	15.012	.001	—.0005	.000	—.004	—.004	—.004	—.004	—.002	—.002	—.002
76	15.010	.003	.001	.002	—.002	—.002	—.002	—.002	—.001	.000	.000
74	15.013	.000	—.002	—.001	—.004	—.005	—.005	—.005	—.004	—.003	—.003
72	15.012	.001	—.001	.000	—.003	—.004	—.005	—.004	—.003	—.002	—.002
70	15.011	.002	.000	.001	—.002	—.003	—.004	—.003	—.002	—.001	—.001

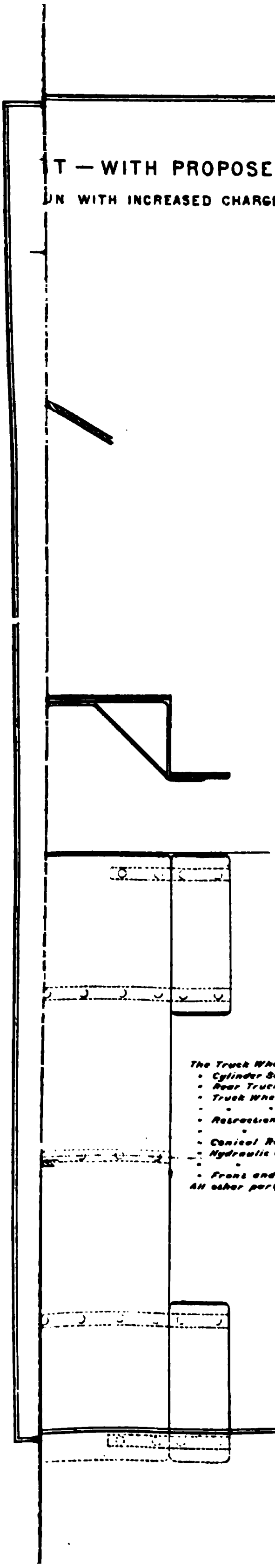
Table of enlargements of 15-*inch Rodman smooth-bore gun, No.* 114—Continued.

Inches from muzzle.	Original diameter of bore, Dec. 21, 1875.	Enlargements after—									
		17 rounds, Jan. 6, 1876.	36 rounds, Feb. 26, 1876.	44 rounds, Aug. 23, 1876.	65 rounds, Aug. 24, 1883.	71 rounds, Aug. 25, 1883.	73 rounds, Sept. 18, 1883.	83 rounds, Sept. 20, 1883.	113 rounds, Sept. 27, 1883.	133 rounds, Oct. 8, 1883.	173 rounds, Oct. 8, 1883.
68	15.011	0.002	0.000	0.001	—0.002	—0.003	—0.003	—0.003	—0.001	—0.001	—0.001
66	15.012	.001	— .001	.000	— .003	— .004	— .004	— .004	— .003	— .002	— .002
64	15.012	.000	— .001	.000	— .003	— .004	— .004	— .003	— .002	— .002	— .002
62	15.012	.000	.000	.000	— .003	— .004	— .005	— .003	— .003	— .002	— .002
60	15.012	.000	— .0005	.000	— .003	— .004	— .004	— .004	— .003	— .002	— .002
58	15.012	.001	— .001	.000	— .003	— .004	— .004	— .004	— .003	— .002	— .002
56	15.012	.001	— .001	.000	— .003	— .003	— .004	— .004	— .003	— .002	— .002
54	15.012	.001	— .001	.000	— .003	— .003	— .004	— .004	— .003	— .003	— .002
52	15.011	.002	.000	.001	— .002	— .002	— .003	— .003	— .002	— .001	— .001
50	15.012	.001	— .001	.000	— .003	— .004	— .004	— .004	— .002	— .002	— .002
48	15.012	.001	— .001	.000	— .003	— .004	— .004	— .004	— .002	— .002	— .002
46	15.012	.001	— .001	.000	— .003	— .004	— .004	— .003	— .003	— .002	— .002
44	15.011	.002	.000	.001	— .002	— .003	— .003	— .002	— .002	— .001	— .001
42	15.013	.000	— .002	— .001	— .004	— .005	— .005	— .004	— .003	— .003	— .003
40	15.013	.000	— .002	— .001	— .004	— .005	— .005	— .004	— .005	— .003	— .002
38	15.012	.001	— .0005	.000	— .003	— .004	— .004	— .003	— .002	— .002	— .001
36	15.012	.001	— .0005	....	— .003	— .004	— .004	— .003	— .002	— .002	— .001
34	15.013	.000	— .002	....	— .004	— .005	— .005	— .004	— .004	— .003	— .003
32	15.012	.001	— .001	.000	— .003	— .004	— .003	— .003	— .003	— .002	— .002
30	15.012	.001	— .001	.000	— .003	— .004	— .003	— .003	— .003	— .002	— .002
28	15.012	.001	— .001	.000	— .003	— .004	— .003	— .003	— .002	— .002	.000
26	15.011	.002	.000	.001	— .002	— .004	— .002	— .002	— .001	— .002	.001
24	15.011	.002	.000	.001	— .002	— .002	— .002	.002	— .001	— .001	.000
22	15.012	.001	— .0005	.000	— .004	— .003	— .004	— .002	— .002	— .002	— .001
20	15.013	.000	— .002	— .001	— .005	— .004	— .004	— .003	— .003	— .003	— .002
18	15.012	.001	— .001	.000	— .003	— .003	— .002	— .001	— .002	— .002	— .001
16	15.013	.000	— .0005	— .001	— .004	— .004	— .004	— .003	— .002	— .003	— .001
14	15.012	.001	— .001	.000	— .003	— .003	— .003	— .002	— .002	— .002	.000
12	15.013	.000	— .001	.000	— .003	— .003	— .003	— .003	— .003	— .003	— .001
10	15.013	.001	— .001	.000	— .003	— .003	— .003	— .003	— .003	— .002	.000
8	15.013	.003	— .001	.000	— .002	— .003	— .003	— .003	— .002	— .002	.001
6	15.014	.003	— .002	.001	— .003	— .004	— .004	— .003	— .002	— .004	.000
4	15.012	.005	.000	.003	— .001	— .002	.000	.002	.001	— .001	.003
2	15.013	.004	— .001	.003	....	— .003	.000	.001	.001	.001	.002
1	15.014	.003	— .001	.003	....	— .002	.001	.003	.001	.001	.001

PLATE I.

T — WITH PROPOSED ALTERATIONS

N WITH INCREASED CHARGE



— MATERIALS —

The Truck Wheel Plates (Upper Carriage)
" Cylinder Stuffing Box
" Rear Truck Wheel Sockets
} are made of Bronze

" Truck Wheels (Upper Carriage)
" " " Journals
" Retraction Gears, Worm and Bearings
" " Rope
" Conical Rollers of Pintle Bolsters
} are made of Steel

" Hydraulic Cylinder
" " " " Heads
} are made of Cast Iron

" Front and Rear Buffers are mad of Rubber
All other parts are of Wrought Iron

Appendix 36—1883.

U.S. Ordnance Board
Governors Island April 3d 1883.

Altered August 28th 1883

APPENDIX 36.

FIRING OF 15-INCH SMOOTH-BORE GUN WITH CHILLED PROJECTILES AGAINST ARMOR PLATES.

(4 plates.)

[Fifth indorsement.]

ORDNANCE OFFICE,
April 18, 1882.

Respectfully returned to the Ordnance Board, U. S. A., inviting its attention to the second and third indorsements hereon. If the alterations* within proposed were ever applied to a 15-inch F. P. carriage, the Board will please render a report thereon.

As the 15-inch S. B. gun is deemed to be still an effective weapon for many purposes of coast defense, it is desired to ascertain what alterations, if any, should be made in the existing carriages to place them in the most efficient service condition. The Board will therefore take the matter into consideration, and submit such plans and recommendations as may seem best calculated to secure this object. The files of this office show the following 15-inch carriages to be on hand at the various forts and arsenals, viz: Front pintle, 152; center pintle, 129; and of this number 105 are provided with pneumatic buffers, and 3 with friction recoil checks, and 11 of the front pintle carriages are of the increased height. There are also on hand, chiefly in the forts, 312 15-inch S. B. guns; and the Board will further take into consideration the most suitable kinds of powder and projectiles and the weights of charges for these guns.

A full report is desired with a view to publishing a memorandum for the use of the artillery service.

S. V. BENÉT,
Brigadier General, Chief of Ordnance.

The fifth indorsement, dated April 18, 1882, on Ordnance Office file No. 1138 of 1877, directed the Board to take into consideration the most suitable kinds of powder and projectiles and the weights of charges for the 15-inch smooth-bore gun. In accordance with the orders of the Chief of Ordnance in the sixth indorsement of March 20, 1883, on Ordnance Office file No. 5333 of 1881, steel and chilled cast-iron shot were to be fired at an armor plate.

The gun was a 15-inch Rodman smooth-bore, No. 114, made at South Boston Foundry, 1865.

The carriage was a 15-inch barbette carriage, increased in height and altered in accordance with the drawing forwarded to the Ordnance Office March 13, 1883.

The armor-plate target, 6 feet by 11 feet in size, was composed of three plates, two of which were 4 inches thick, and the third 2 inches thick, making a total thickness of 10 inches, backed by two layers of oak timbers each 10 inches square, and a 1-inch skin plate of wrought iron. These were firmly bolted together by cylindrical wrought-iron bars 2.5 inches in diameter, which were countersunk in the 2-inch face plate, and, besides penetrating the plates and timbers above referred to, passed through wrought-iron channel beams 0.75 inch thick. The channel beams supported the upper ends of heavy oak struts, which at their lower extremities were mortised into horizontal beams imbedded in the sand. To increase the resisting power of the target, sand was thrown up in its rear and between the struts. The arrangement of the whole device is illustrated in the accompanying plate, marked I.

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* Major Parker's design for substituting rollers for the bolster and eccentric axle in the chassis of the 15-inch carriage.

The projectiles were 15-inch spherical shot of steel and chilled cast iron. The steel shot were some that remained on hand after the firing which took place at Fort Monroe and Fort Delaware in 1868. Their purchase by the Chief of Ordnance was approved by order of the Secretary of War February 16, 1864, and they were procured through Naylor & Co., of New York, from John Brown & Co., of Sheffield, England. The chilled cast-iron shot came from the Farrel Foundry and Machine Company.

The trial commenced August 22, 1883. The first question proposed was the determination of the most suitable charge of powder for the gun. Records heretofore published of the firing of a charge of 125 pounds of E. V. powder showed that no undue strain was exercised by it on the gun. A charge of 125 pounds was therefore fired with a 450-pound projectile, giving a pressure of 17,500 pounds. The charge was then increased to 130 pounds, with which the pressure was 20,500 pounds, and a muzzle velocity of 1,676 feet was obtained. The pressure was such that a higher charge might have been used, but small fragments of unburned powder were found near the gun after this round, indicating that a higher charge would be less completely consumed, and it was thought that an increased charge would enhance the pressure without augmenting the velocity correspondingly. This charge, therefore, of 130 pounds was taken as a basis for the calculations required in the subsequent operations. Analysis showed that the striking velocity of the shot when it had traversed a distance of 1,000 yards would be 1,250 feet. In order to insure striking the plate at the point aimed at, it was placed 200 yards from the muzzle of the piece. As it was desired to ascertain the effect against a plate target 1,000 yards distant, the charge had to be decreased. To obtain a first approximation to the decreased charge required, use was made of the following formula:

$$p'=\left(\frac{V'}{V}\sqrt{p}\right)^2$$

In which—

V is the muzzle velocity obtained.

p is the charge giving V.

V' is the velocity desired.

p' is the charge required to give V'.

Analysis showed that if a muzzle velocity of 1,676 feet gave a remaining velocity of 1,250 feet at 1,000 yards, a muzzle velocity of 1,322 feet would give the same remaining velocity at 200 yards. Substituting numbers in the above formula we have—

$$p'=\left(\frac{1322}{1676}\sqrt{130}\right)^2=80.145.$$

A charge of 80 pounds gave a velocity within 20 feet of that desired.

A second approximation gave 82.25 pounds as the charge and the resulting velocity was too great by 20 feet. A charge of 81 pounds was then adopted as that required when the target was placed 200 yards from the muzzle, in order to simulate firing with 130 pounds at 1,000 yards with a 450-pound projectile.

In the first round against the plate (No. 63 of the record) a steel shot weighing 482 pounds was to be fired, and it was necessary that for comparison it should have the same amount of energy when it struck the plate as the 450 pound projectile moving with a velocity of 1,250 feet. The energy of the latter projectile expressed in foot-tons was—

$$\frac{WV^2}{2\times g\times 2240}=\frac{450\times 1250^2}{32.16\times 4480}=4880.$$

and the steel projectile would have the same *vis viva* if it struck with a velocity of 1207.8 feet. The gun being fired, the striking velocity was found to be 1207 feet and the energy in foot-tons 4873.8. The projectile struck the target, forcing large fragments of the plates into the backing and indenting the latter to a depth of 9.25 inches, bending the skin plate and channel beams. The projectile rebounded and was found flattened, enlarged in diameter and cracked as shown in Plate II.

The next round (No. 64 of the record) was composed of a chilled cast-iron shot with a charge of 81 pounds of powder. Its striking velocity was 1,231 feet and its energy was 4,766 foot-tons, 107.8 less than that obtained in the preceding round; the effect, however, was much greater, as the iron plates were penetrated and large fragments of them were forced 21.25 inches into the backing. The skin plate was bulged out in rear and the channel beams bent and cracked, while the struts in rear of the point struck were driven out of place. The shot, breaking into several large and numerous small fragments, remained in the plate.

The destructive effects of the chilled shot were so much greater than with the steel shot, although the former possessed less energy, that it was not deemed necessary to continue the comparison of their efforts at 1,000 yards any further, and it was determined to fire a second chilled shot with 130 pounds at 200 yards, as such ranges may be used in action under certain circumstances.

The third round (No. 65 of the record), composed of a chilled cast-iron shot and a charge of 130 pounds of powder, reached the plate with a velocity of 1,557 feet and an energy of 7,690 foot-tons. It struck the target at a point 12 inches from the upper and 18 inches from the right-hand edge, penetrated entirely through the plate, backing, and distorted the skin plate, drove the right side of the target back 30 inches and moved it bodily to the right 16 inches. The exterior chilled portion of the shot broke into many fragments, while a mass weighing 190 pounds was found in rear of the plate. The bolt through the face plate was snapped and bent, the channel beams in rear were broken, the struts driven from place and splintered, and the right upper part of the target badly shattered, as shown in Plates III, IV.

The charge used causes the gun to recoil almost to the counter-buffers when the proper amount of liquid is put in the hydraulic buffer-cylinder, and renders the further use of pneumatic buffers impracticable with these carriages.

The results of this firing indicate that the most suitable charge of powder for the 15-inch gun is 130 pounds, and that chilled cast-iron projectiles should hereafter be used. With our improved powders and projectiles the projectile energy of this gun has been increased to an extent which renders it not only an efficient weapon for secondary defense, but even formidable as a primary gun for racking in many of our harbors.

GEO. W. McKEE,
Major of Ordnance, senior member present.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 15-inch Rodman smooth-bore gun No. 114,

[Gun mounted on 11-inch hydraulic ca

	Number of fire.	Time.	Powder.		Projectile.		Elevation in degrees.
			Kind.	Weight.	Kind.	Weight.	
		1883.		*Lbs. Ozs.*		*Lbs.*	
A. M.—Barometer, 30.069; thermometer, 83; humidity, 58; wind, 15 miles an hour.	59	Aug. 22	Du Pont's hexagonal E. V. M. Density, 1.750; granulation, 72.	125 00	Round shot (new)	450	—
	60	Aug. 22	......do	130 00	....do	452	—1
	61	Aug. 22	......do	80 00	....do	453	—
P. M	62	Aug. 22	......do	82 04	....do	452	—1
A. M.—Barometer, 29.996; thermometer, 86; humidity, 68; wind, 12 miles an hour.	63	Aug. 23	......do	81 00	Round shot, steel, (new).	482	—1
P. M.—Barometer, 29.912; thermometer, 91; humidity, 66; wind, 12 miles an hour.	64	Aug. 23	......do	81 00	Round shot, iron chilled.	453	—1
	65	Aug. 23	......do	130 00	....do	457	—1

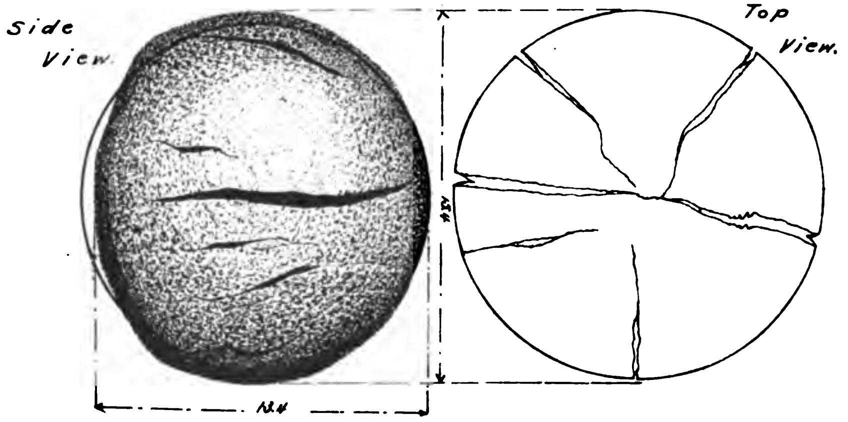
at Sandy Hook, N. J., from August 22 to August 23, 1883.

riage, altered from a 15-inch carriage.]

Pressure, pounds per square inch of bore.	Instrumental initial velocity, 108 feet from muzzle.	Recoil.	Wind, strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
	Feet.	*Feet.*			
17, 500	1, 618	6. 17	From front and left, 17°; 15 miles an hour.	Fired into sand butt. At round 59, dog which catches in rack to prevent carriage running in battery was broken, and pieces were removed and carriage allowed to run in battery during the remaining rounds.	
20, 500	1, 658	6. 25	....do		
8, 500	1, 288	5. 67	....do	Fired at 200-yard target.	
10, 500	1, 345	5. 62	....do		
8, 000	1, 259	5. 46	From front and right, 38°; 12 miles an hour.	Fired at 200-yard iron target (normal). Gun washed out, examined, and star-gauged.	Shot cracked; found 9′ 4″ from target. Right hand side of target thrown back 12¼″ and to right 11⅜″. Penetration, 19″ 25. (See plates.)
8, 000	1, 288	5. 50	From front and right, 2°; 12 miles an hour.		Shot broken into small fragments, the greater part of which remained in the target. Right-hand side of target thrown back 9⅜″, and left hand side 9″, and entire target thrown to left 11″. Penetration, 31″.25. (See plates.)
20, 000	1, 635	6. 25	....do		Shot passed through target and found lodged between the one-inch rear plate of target and one of the rear braces. Right side of target thrown back 2′ 2″ and entire target thrown. 16″ to right. (See plates.)

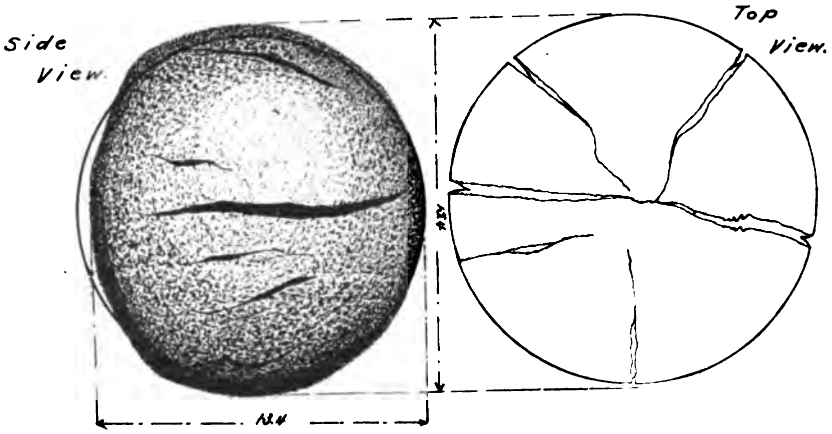
PLATE II.

STEEL SHOT AFTER FIRING



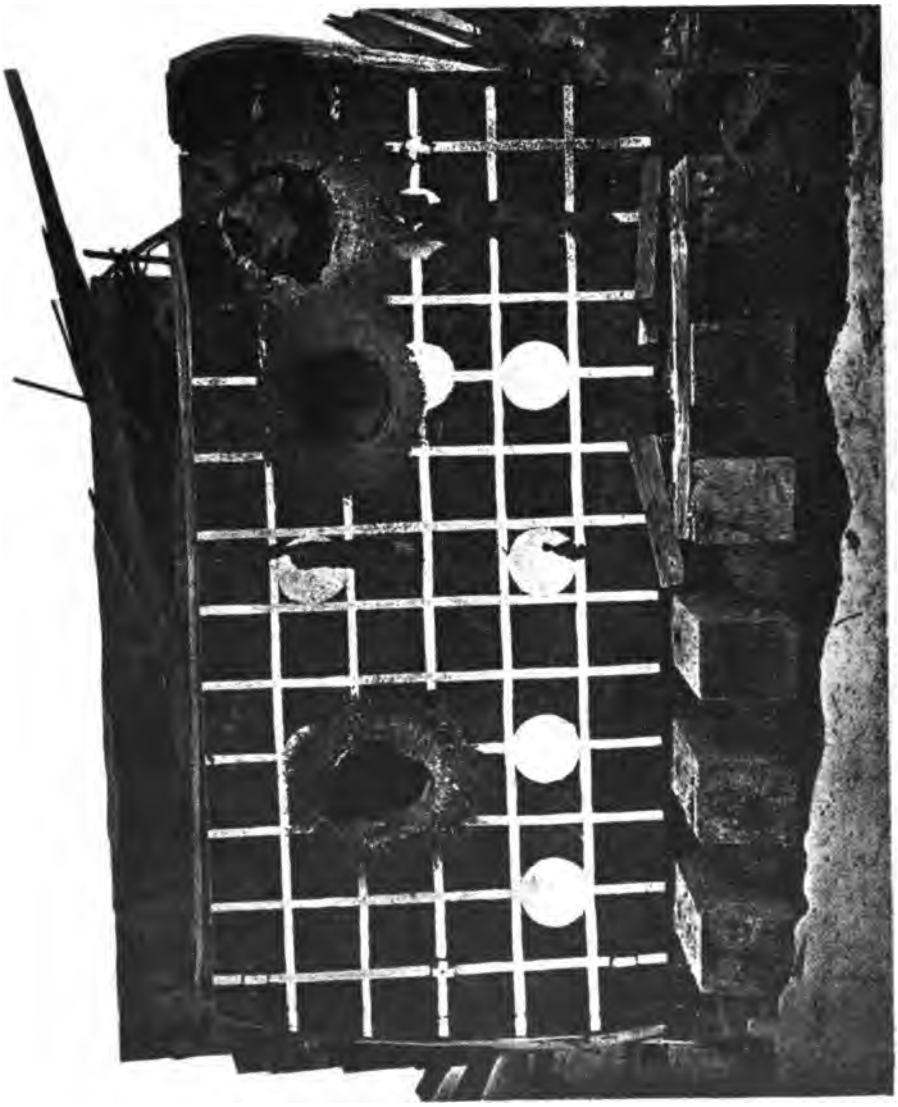
Heavy line shows original size. U. S. Ord. Bd.
Governors Island Sept. 14th/1883.

STEEL SHOT AFTER FIRING



Heavy line shows original size. U. S. Ord. Bd.
Governors Island Sept. 14th 1883.

[illegible] CHILLED IRON SHOT ON 10 INCH ARMOR.



No. 3 (Round 65)

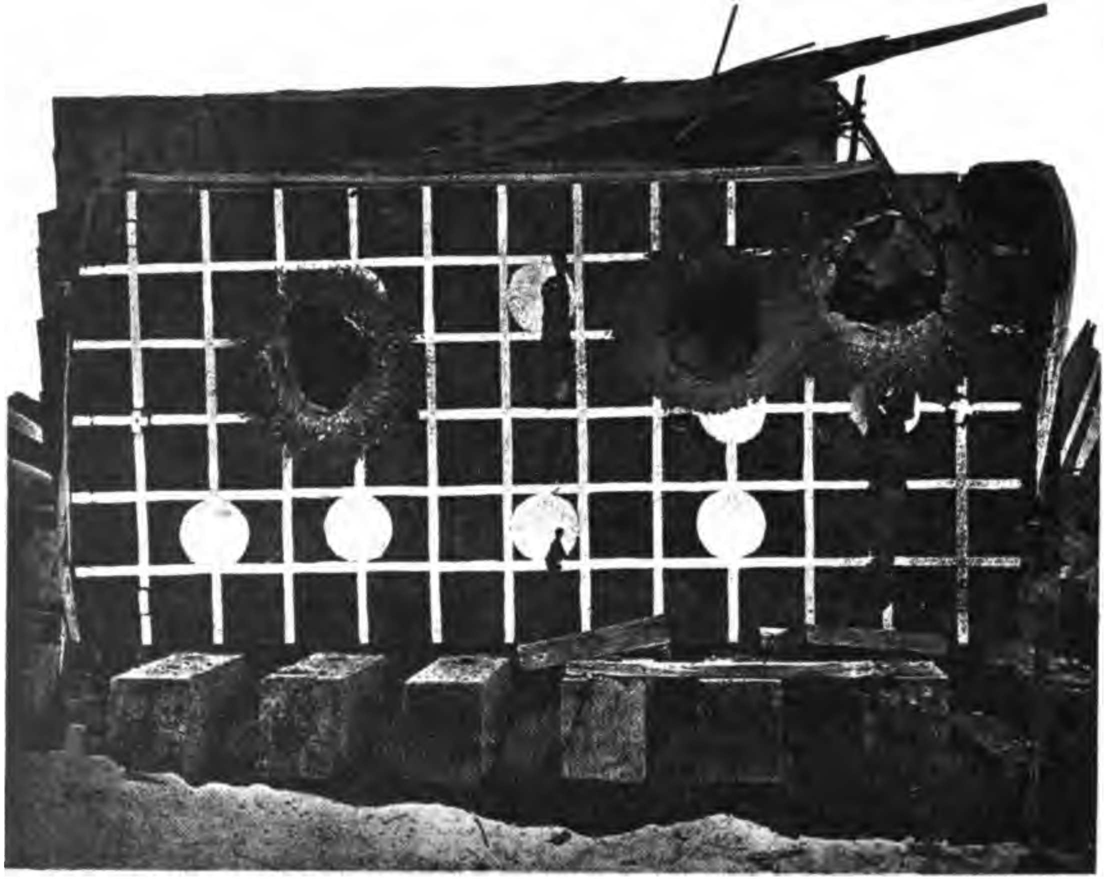
No. 1 (Round 63)

No. 2 (Round 64)

Appendix 21 1883.

PLATE III.

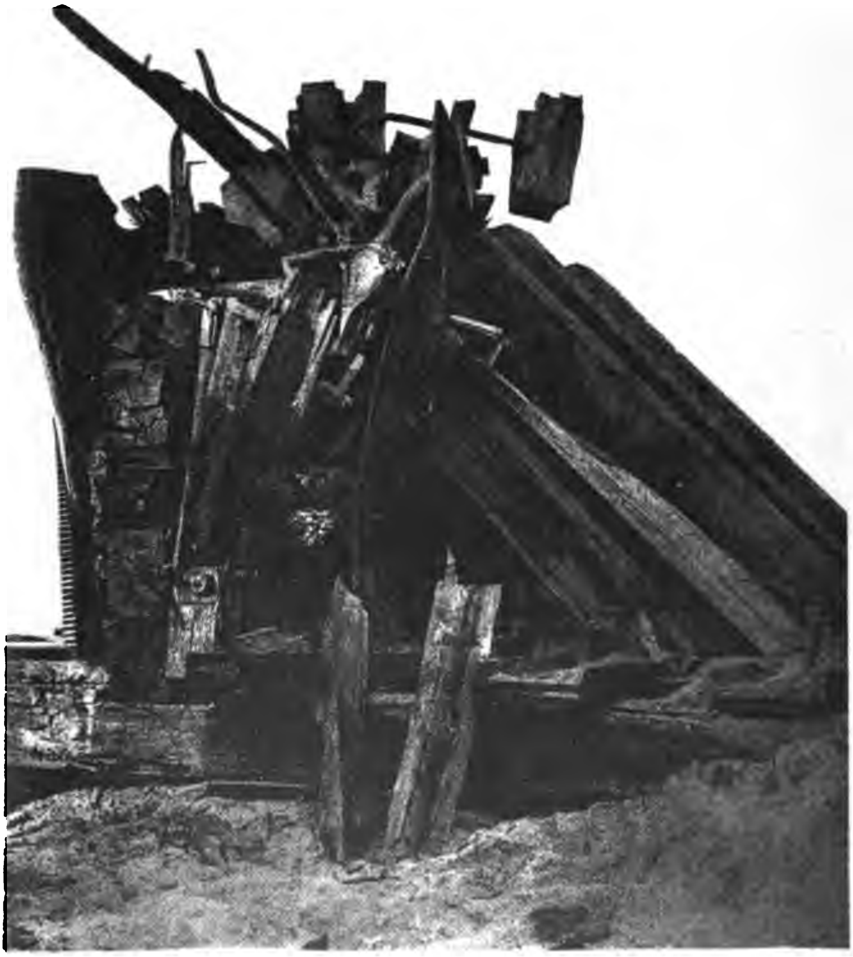
EFFECT OF STEEL AND CHILLED IRON SHOT ON 10 INCH ARMOR.



Appendix 21 1883.

PLATE IV.

EFFECT OF STEEL AND CHILLED IRON SHOT ON 10 INCH ARMOR



Appendix 21 1883.

No 3
(Round 65)

APPENDIX 37.

TRIAL OF L. A. MERRIAM'S 3-INCH RIFLE.

(1 plate.)

This gun was presented for trial to the Chief of Ordnance, in inclosed letter of Mr. J. H. Work, of June 20, 1882, which was referred to the Ordnance Board by indorsement of June 21, 1882, and the writer accordingly communicated with. The gun and ammunition were then examined and report made by the Board in its indorsement of June 26, 1882. By third indorsement of Chief of Ordnance of June 28, 1882, the Board was directed to test the gun, provided the projectiles could be used, and make report to the Ordnance Office. The Board, on the invitation of Mr. Work and the inventor, Mr. Merriam, visited the Delamater Iron Works to see the gun taken apart before it was sent to Sandy Hook for trial. After being received at Sandy Hook a siege-gun carriage was altered upon which it was mounted, and a pressure gauge was inserted in the breech screw. On February 19, everything being in readiness for the trial, Mr. Work and Mr. Merriam were written to and informed that this would take place at Sandy Hook, on February 21. Mr. Merriam presented himself at the appointed time and the trial commenced. Mr. Merriam stated in a communication written by Mr. Work prior to the trial that he thought a suitable proportion between the initial charge and the chamber charge was 20 or 30 to 1. A few cartridges with ¼ pound charge had been prepared for the initial charge, proposing to use (in the proportion of 20 to 1) 5 pounds for the chamber charge, but at the suggestion of Mr. Merriam this was increased to ½ pound, the latter charge remaining the same.

The results of this round are given in the inclosed record. At Mr. Merriam's suggestion, and from an examination of the low pressure obtained, it was determined to increase the charges to 1 pound for the initial charge and 8 pounds for the rear charge. In the first round the rear charge was inserted through the aperture on the top of the chamber of gun, but this caused the powder to be heaped up in the center, necessitating its being leveled off. At the suggestion of Mr. Merriam, at the second round small cartridges of 1 pound each were inserted through the breech screw hole, but it was found that not more than 6 pounds could be comfortably inserted in this way, and the other 2 pounds were, in consequence, put in through the top aperture. The gun was jarred to prevent the powder from crowding over the top and to settle it around the cartridges. The result of this round is given in the record of firing, showing a violent tangential rupture, and indicating that a very high pressure must have obtained. The total capacity of the chamber was 10.75 pounds of powder, and the maximum amount of powder for initial charge that could be used with the wooden diaphragms and connecting stem provided was 1 pound. The air space for an 8-pound charge in

Record of firing with L. A. Merriam 3-inch rifle at Sandy

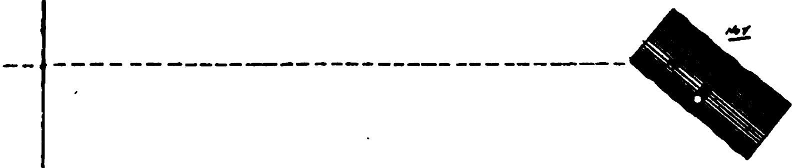
	No. of fire.	Time.	Powder.			Projectile.		Elevation in degrees.
			Kind.	Weight.		Kind.	Weight.	
				lbs.	*oz.*		*Lbs.*	
Barometer, 30.022; thermometer, 29; humidity, 77; wind, 34 miles an hour.	1	1883. Feb. 21	Front charge	0	8	Whitworth projectile 6" long. Length of flat portion of sides, 4½".	8	−¼
			Charge in chamber.	5	0			
	2	Feb. 21	Front charge	1	0	Whitworth projectile, 7½" long. Length of flat portion of sides, 5½".	10	−¼
			Charge in chamber.	8	0			

Hook, N. J., from February 21 to February 21, 1883.

Pressure, pounds per square inch of bore.	Instrumental velocity, 95 feet from muzzle.	Recoil, feet.	Direction of wind as regards line of fire.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
18,000	*Feet.* 1,657	4.50	From rear and right.	Inserted from muzzle. Fired into sand butt. Gas got into pressure plug. Inserted loose through aperture on top of chamber.
*130,000+	1,284	4.00		Inserted from muzzle. Fired into sand butt. Six pounds of this charge were inserted in one-pound cartridges through breech screw-hole and two pounds loose through hole on top of chamber. The cylinder screwed on to the gun proper and containing the chamber-charge burst explosively at this round into eight pieces—all the fragments being recovered and their position and distance from the gun noted on sketch accompanying this record, with the exception of the top left portion of the cylinder, which could not be found, and it is believed that it was thrown into the ocean, as a large piece was seen to fall in the water at the time of bursting. The top right portion of cylinder, marked on the accompanying sketch ‡7, was thrown to the right a distance of 700 feet—this piece weighing 404 pounds. Carriage on which this gun was mounted disabled by having its stock broken and split. Breech-screw, or plug, running through breech of gun, contained the pressure-plug, and when recovered it was found that the pressure-plug was jammed into the breech-plug so tightly as to make it impossible to remove or open it in the ordinary way, and it was necessary to cut the breech-plug away from around it. The pressure-plug on being thus removed was found to be broken in two, the piston tightly jammed and likewise broken—the disk was cut nearly through and bore on its sides indentations made by the shoulders or sides forming the seat on which it is supposed to rest when it received the knife cut.

* Could not be accurately measured, but estimated at over 130,000 pounds per square inch.

PLATE I.



Appendix 37—1883.

APPENDIX 38.

REPORT OF THE PRINCIPAL OPERATIONS AT THE ROCK ISLAND ARSENAL, ILLINOIS, DURING THE FISCAL YEAR ENDED JUNE 30, 1883.

LIEUT. COL. D. W. FLAGLER, ORDNANCE DEPARTMENT, COMMANDING.

(9 plates.)

SHOP I.

(A wood-working and leather-working shop for the arsenal.)

This shop has been completed during the year. It was commenced in August, 1878.

The principal work done is as follows: The roof has been put on; the brick fire-proof arches for all the floors have been put in; a stone and concrete basement floor has been put in; the iron stairways have been built; all the doors, windows, and other wood work have been put in; and the whole building has been plastered and painted. The sewers have also been put in; the area walls have been built, and all the grading around the building; laying of stone walks, and area copings, and macadamizing of court and roads have been completed.

This completes the last of the five shops in the arsenal row.

This shop is built of Anamosa limestone, from Jones County, Iowa. Tests, and the experience already had with this stone, show that it is certainly more durable than the Joliet stone used in the other buildings; and the stone also gives a handsomer building, which was not expected. Next to shop G, it is the handsomest and probably the best of all the shops at the arsenal.

Attention is invited to the cost of this building. Its total cost, including sewers, water mains, steps, platforms, areas, roads, walks, grading around the building, and grading and macadamizing the court, has been $328,500. This is less than one-half the cost of the first shops that were built, and yet the building is, in some respects, better built and finished.

SHOP H.

(An iron-finishing shop for the armory.)

This shop was commenced in August, 1878. The work done on the building during the year is as follows:

IRON WORK.

All the iron beams for the third floor have been purchased and fitted in the arsenal shops; the iron columns, caps, and bases for this story have been cast and fitted in the arsenal shops, and this iron work has been put up.

STONE WORK.

The stone for the third story has been purchased and cut, and the walls of this story nearly completed.

WOOD WORK.

About 620,000 feet of the lumber required for this building has been purchased and stacked for seasoning, and the manufacture of the doors, door frames, window sash and frames for the building is in progress in the arsenal shops.

SHOP K.

(A finishing and stocking shop for the armory.)

This shop was commenced in July, 1881. The work done on this building during the year is as follows:

All the stone for the basement story and the first story has been purchased and cut.

The walls of the basement story, including the 76 stone piers for supporting the floors, have been built, and about three-fourths of the next story has been built.

All the iron beams for the first floor have been purchased and fitted in the arsenal shops; the iron bases have been cast and fitted, and this iron work put in position.

STOREHOUSE.

This building is located at the point marked Storehouse A, on the accompanying map.

Except the storehouse at the west end of the island, which was commenced in 1864 and completed in 1869, this is the first storehouse commenced at the arsenal. Full detail plans, drawings, and specifications for the building were completed by me and submitted to the Chief of Ordnance in April, 1883, and approved by him April 17, 1883.

The building is in plan 234 by 60 feet, and has two porticos, each 15 by 60 feet. It has four floors, making the total area of floors 63,600 square feet, and each of the supported floors has sufficient strength to carry a load of 400 pounds per square foot.

The walls are of stone, and the architecture somewhat similar to that of the adjacent shops. Drawings of the building are submitted herewith (Plates II, III, IV, V, and VI), and a more detailed description is given in Appendix A to this report.

Ground for the building was broken April 16, 1883, and during the fiscal year the excavations for the basement story and foundations have been completed; the foundations have been put in; stone purchased for, and the walls of about two-thirds of the basement story built.

Nearly all the excavations were in rock and clay, and as the foundations are all in good solid rock, no drawings and descriptions of the same have been preserved. Provision has been made for perfect drainage of the foundations, basement story, areas, and ramps.

The foundations of this building are built entirely of Portland cement concrete. When the depth of foundation below the plane of the basement floor exceeded 4 feet the footing stones were laid on the beton as soon as a height of 4 feet was reached and the main walls of the building commenced at this point, so that the footing stones are at uneven heights. This is believed to be a better plan than carrying the foundation masonry all up to an even height at the basement floor, and then laying the footing stones in an even course. The sill and water-table courses which are respectively 5 feet and 10.5 feet above the basement floor, really perform the work of footing courses.

BETON AND CONCRETE FLOORS AND WALKS.

As I have bestowed much attention upon the preparation of the beton and the construction of the concrete floors mentioned in this report, a description of the methods employed and of the results obtained as regards quality and cost may be of use to the Department. The cement used is the "South Bend Portland," made at South Bend, Ind. Tests and experience have given better results with this cement than with the best imported English cements that could be obtained here. It costs now, delivered at the arsenal, $2.85 per barrel of 400 pounds.

The sand, of good sharp quality, is obtained at various places in the vicinity, and has cost this season, delivered in wagons at the work, 63 cents per cubic yard. The rock, a tough and very hard limestone containing much flint, had been excavated in the water-power canal, and was hauled across the river on the ice during the winter, and cost, delivered at the work, 50 cents per cubic yard. It was crushed with a Totten crusher. For the foundation work, the crusher was placed at the edge of the basement excavation (about 7.5 feet deep), and the rock fell from the crusher on a plank platform at the bottom of the excavation. A sprinkler kept the pile of broken rock thoroughly wet. It was then shoveled into barrows and dump boxes and thoroughly mixed with the sand and cement as shoveled. The ingredients were measured in boxes until the workmen became expert enough to measure accurately with shovels.

The crusher was not moved during the work. When the foundation work was near, the concrete was wheeled to it in barrows. When distant, it was pushed in dump boxes of one cubic yard capacity, on cars, on the same tramway that was afterwards to be used for delivering stone and mortar to the derricks for building the walls. The concrete was not wet until it arrived at the place of use, and just the instant before it was dumped into the foundation excavation, that the cement might not be injured by previous setting.

The gauge for the amount of water used was that when a layer of the concrete was thoroughly rammed and tamped its surface should be just covered with water.

INGREDIENTS AND COST.

1 cubic yard of crushed rock—cost before crushing	$0 50
⅓ cubic yard of sand at 63 cents	0 21
⅙ cubic yard of cement equal to 1 barrel, 400 pounds	2 85
Cost of material per yard	3 56

The capacity of the crusher is 33 yards per day.

Labor for making and putting in 33 cubic yards of concrete: 2 men at crusher; 2 mixing sand and cement and bringing it to crusher; 2 mixers; 2 wheelbarrow men; 2 tampers—10 men in all, at $1.50 per day each	$15 00
Cost of running crusher	2 75
1 mason, superintending	2 75
Miscellaneous expenses	2 00
Total for 33 yards	22 50
Labor for 1 yard	0 68
Materials for 1 yard	3 56
Cost per yard	4 24

CONCRETE FLOORS FOR BASEMENTS.

Spawls and refuse rock are hauled and spread over the site of the floor to a depth of 4 to 5 inches, and the surface of the same is broken by hand with a stone hammer.

In this stone are then set on edge wood strips 1.5 by 5 inches, so as to divide the floor into blocks 3 to 4 feet square. (See Plate VII.) On the rock is then tamped a layer of 3.5 inches of concrete, of the same quality, and prepared, as has been described. The top of this layer is made even with the tops of the wooden strips. The strips are then removed and a layer 1.5 inches thick of cement mortar (1 of cement to 2 of sand) is laid on the concrete with a trowel, then floated and troweled again. being made perfectly level and even with a straight edge. This mortar fills the spaces from which the strips were removed.

Then the blocks are divided by cutting carefully down with a trowel to the bottom layer of rock as exactly as possible along the center of the space from which the strips were removed. A straight edge is used to guide the trowel. Plate VII shows the finished floor after it has been cut, and also just before the wooden strips have been removed. The layer of cement mortar not only covers the top of the block but the edges also.

Walks are laid in precisely the same manner as has been described for floors.

By using ochers, umbers, lampblack, marble and granite dust when the surface is floated, various colors and handsome effects may be produced. For roadways, the layer of concrete is made 5 inches thick and the top dressing is lined like a Russ pavement to prevent animals from slipping.

The object sought at first in cutting the floors and walks into square blocks was to prevent cracking from settling and the action of frost. Observation of these floors leads me to believe that it is not settling and the action of frost that crack concrete floors so much as *shrinkage of the concrete.*

The joints between the blocks when first cut are, of course, the thickness of a trowel, say one-sixteenth of an inch. At the end of three months, the opening of these joints shows a shrinkage in a block 3 feet square of one-eighth of an inch. This shrinkage must crack the floor, no matter how well laid.

For test, I laid some of this concrete nearly two years ago out of doors, where it is exposed to frost and to the wear of wagons. It has not yet showed any signs of failure. Its cost is less than one-half the cost of paving or flagging, and gives a much handsomer, and, I think, except for roadways, a much better floor.

The cost of the floor and walks at this arsenal is 14 cents per square foot.

One mason and two laborers lay 224 square feet per day. After the broken refuse rock has been put in, the materials required for 224 square feet are: 2 yards crushed rock, 2 yards sand, 1 yard (6 barrels) cement.

GENERAL CARE, PRESERVATION AND IMPROVEMENT.

Nearly all of the appropriation under this head has been expended in the necessary care and preservation of the extensive arsenal grounds, river banks, buildings, roads, walks, gutters, sewers, water pipes, &c.,

and the extensive dams and other constructions pertaining to the water power and the wagon bridges to the cities of Rock Island and Moline.

The other important items of work under this head performed during the year are as follows:

About one-half of Fort Armstrong avenue has been newly macadamized with twelve inches of rock and gravel. About 2,800 yards of ditches have been cut for the better drainage of the low swamp lands of the island. A 12-inch sewer-pipe, 4,000 feet long, has been laid from a point near the Moline bridge, down along the water-power dike, to connect with the iron drainage-pipe under the water-power pool. This new pipe is to drain about 50 acres of land near the Moline bridge, the drainage of which was cut off by building the dike and where standing water every spring has been a nuisance. Attempts have been made to drain this land with a ditch, but quicksands along its route, soaked with water from the pool, rendered its maintenance impracticable.

The greater part of the materials obtained in excavating for the storehouse were used in continuing the fill (begun eight years ago) across the low lands, south of the storehouse, for continuing West avenue south toward the river. This is the part marked X Y on Plate I. About 3,500 yards of mixed rock and clay excavation were utilized in this way.

Also a heavy cut for the avenue has been blasted through the plateau of rock near the laboratories.

As none of this work was completed at the close of the fiscal year, a further description of it is deferred until next year.

A 34-ton Fairbanks railroad-track scale has been put in the main railway track at the point marked T on Plate I. It is estimated that the saving in cost of weighing coal, cement, lime, and iron alone should pay the cost of the scales in about one year.

I feel it my duty to again call the attention of the Department to the inadequacy of the appropriation under this head. It is very important that the improvement of the grounds, construction of roads, avenues, &c., should be carried on simultaneously with the other work, yet I find that the roads, bridges, railroads, water power, and especially the grounds and buildings, have now become so extensive that with the utmost care in expenditure the amount appropriated for these purposes is not sufficient for proper care and preservation alone.

MACHINERY AND SHOP FIXTURES.

The principal items of work under this head during the year are as follows:

The main lines of shafting, 1,200 feet in all, and two power elevators for shop G have been manufactured in the arsenal shops and put up.

Some extensive repairs of the water-power and transmission machinery have been made.

A few machines much needed for immediate use have been purchased. The most important of these are a new power-hammer, and a large punch and shear for the arsenal forging-shop. The latter is an important machine in the permanent plant of the arsenal. It is a double machine of the best pattern, and weighs 19 tons, and has sufficient power to punch cold a 2½-inch hole in 1½-inch iron, and to shear cold a 3-inch round bar. It is specially adapted for heavy press-work in connection with the economical construction of steel and iron gun carriages.

The improvements of the machinery in the rolling-mill mentioned in my last annual report have been completed and put in operation, and are found to be entirely satisfactory.

Plate VIII, transmitted herewith, shows the locations of the iron heating furnace over which the new boiler is placed; the steam hammer and new engine which receive steam from the boiler, and the fan and heavy shear driven by the engine. The necessary shafting and fixtures for connecting these have been put in, together with a telegraph and other appliances for transporting heavy hot billets from the furnaces to the hammer, and for handling them while at the hammer.

The boiler and its brick work are supported over the furnaces in the ordinary way by a heavy iron frame. Elevation drawing, Plate IX, shows a new device for controlling the amount of heat admitted to the boiler. The large fire brick or block M, when in the position shown on the drawing, closes the direct chimney flue and sends the heat under and back through the boiler flue to the chimney again.

When the boiler is not required, and a stronger draft is required for heating iron only, or what is more likely to occur, a larger amount of heat is sent through the boiler than is wanted for making steam, causing the noisy nuisance of blowing off steam, the block M can be pushed or partly pushed out to its dotted position, thereby sending the heat or any desired portion of the same directly up to the chimney flue. This is found to work satisfactorily. Provision is made for renewing the block M when destroyed by heat.

WATER POWER.

An appropriation was made by Congress in the act providing for the sundry civil expenses of the Government, approved August 7, 1882.

For deepening the water-power canal, which is a portion of the tail race devoted to the exclusive use of the Moline Water Power Company.

For removing a portion of the great stone dike just east of the canal and substituting therefor a new masonry dam with six new waterways and gates, also for the exclusive use of the Moline Water Power Company. And for improving the water-power pool by cutting a channel from the head of the pool through the rock down to a point near the Moline bridge and by farther extending the wing-dam.

The act required the Moline Water Power Company, at its own expense, to deepen the upper end of its own tail race which lies between the upper dam and the Moline shore.

Besides improving the water power, the act of Congress mentioned required a contract to be made with the Moline Water Power Company, whereby the completion of the work specified was to be accepted by the Moline company as a full and final development of the water power as required by previous contracts, and also as a full and final satisfaction of all claims and complaints made by said company against the United States in regard to matters relating to the water power.

This contract involved important interests to the United States, and considerable difficulties and delays occurred in settling its terms with the company, so that it was not finally signed until September 12, 1882. A copy of the contract is appended hereto, and marked Appendix F. Among other things the company raised points in regard to a privilege guaranteed to the United States in a prior contract to use for its own purposes the building stone quarried by the United States; the company desiring the right to sell for its own benefit all this stone. I commenced putting in the necessary coffer-dams as soon as the contract was finally signed, and pushed the work in every possible way from that time till December 27, when I was compelled to abandon it. The delay in signing the contract lost much valuable time, so that it was late in the season for such work before it was commenced. Then the river continued unusually high, with some rapid rises caused by heavy rain which rendered it impossible to maintain the coffer-dams intact. I had nearly a mile in all of these coffers, some of which were additional coffers rendered necessary by the high water. The work was flooded several times, causing delays and great additional expense for repairs, pumping out, and reclearing the work. Finally, in December, intense cold weather set in, the thermometer falling to 18° below zero, and ice gorges in the river made it impossible to maintain the coffer-dams any longer, and I was compelled to abandon the work at the date given above, December 27.

With strenuous efforts I had succeeded in practically completing the new water-power dam for the Moline Water Power Company; had accomplished rather more than one-half of the work in the canal, and about one-third of that in the pool. (The Water Power Company had barely commenced their work.) All this water-power work was resumed this season; is now being very successfully prosecuted, and I hope to complete it in about two months, and so settle the many vexed questions growing out of the numerous contracts which have harassed the Department for the last fifteen years.

A full report and description of the work is deferred until next year, when it is hoped the work will have been completed.

Respectfully submitted.

D. W. FLAGLER,
Lieutenant-Colonel of Ordnance, Commanding.

APPENDIX A.

STOREHOUSES.

ROCK ISLAND ARSENAL.

Plate II is a plan, and shows construction of floors.

Plate III is a front elevation, showing architecture and character of masonry, and gives section of wall.

Plate IV is an end elevation.

Plate V gives a cross-section of wall, and shows construction of floors, piers, and columns.

Plate VI is a map, showing location of storehouse with reference to shop A and avenues, and arrangement of roadways, roads to basement, and railroad track for service of the building.

The architecture and external stonework are made to conform closely in appearance to that of the adjacent shops, with such changes as are necessary for conformity to the character of the building.

The exterior of the building is made fire-proof like the shops. It has an iron roof frame, and is to be covered with slate and copper.

The floors are to be covered with 1½-inch hard yellow pine flooring, planed and matched, and are calculated to carry a uniformly distributed load of 400 pounds per square foot.

The caps, sills, arch, jamb, and all entablature stones that come through the wall are to be finished inside with fine bush-hammered work; the remainder of the interior wall, to avoid plastering, to be faced with cream-colored pressed Milwaukee brick laid in black mortar. This should give not only a handsome interior, but also an economical finish that can never be injured or defaced by piling boxes or stores against it, and will save cost in care and preservation.

The ceilings, including stringers, and all interior woodwork to be plastered with three coats, including a hard finish. The basement floor is to have heavy cut-stone roadways, the remainder of the floor to be laid in Portland cement concrete, with hard finish. The ceiling of this story is 11 feet high, and the story dry and well lighted.

There are easy roadways for teaming heavy articles to all parts of the basement story, and besides this facilities on the first floor for loading and unloading simultaneously five wagons and two railroad cars, and one power and two hand elevators, connecting all the floors. Considering the demands that would be made upon the building during active operations, I do not consider these facilities excessive.

The total estimated cost, including all grading, walks, roadways, and finish around the building, elevators, sewers, water supply, and ventilating, drying, and warming arrangements, is $109,300.

I have given much careful study to the plans for the building for several years, taking advantage of the experience gained in other similar construction work, to obtain a simple construction with correct architectural engineering, to reduce cost, and prevent expense for future care and preservation.

For comparison, I would state that the building is a little more than one-half larger than the old storehouse at the west end of the arsenal grounds; its storage capacity is more than twice as great; the plans embrace a better construction and handsomer building in all respects, and the estimated cost is about two-fifths.

APPENDIX B.

AGREEMENT WITH MOLINE WATER POWER COMPANY IN REGARD TO DEEPENING THE WATER-POWER CANAL, CONSTRUCTING A NEW DAM FOR USE OF THE MOLINE WATER POWER COMPANY, AND THE IMPROVEMENT OF THE WATER-POWER POOL.

Whereas an act making appropriations for sundry civil expenses of the Government for the fiscal year ending June 30th, 1883, and for other purposes, contains the following provisions, to wit: For water power at Rock Island Arsenal, at Rock Island, Ills.: For completing the improvement of the water-power pool, thirty thousand dollars; for deepening the canal, fifty-five thousand dollars; for placing in the wall or dike six new openings for water wheels, fifteen thousand dollars, and the unexpended balance of the appropriation of fifty thousand dollars for developing and maintenance of said water power under the act of June 16th, 1880, and the unexpended balance of fifty thousand dollars for continuing the improvement of the water-power pool under the act of March 3d, 1881, and hereby reappropriated and made available for the purpose named in said acts, provided that no part of the said moneys hereby appropriated for completing the said water power shall be expended until detailed plans and specifications for actual work to be done, the estimated cost of which shall be within the said appropriations, shall be prepared by the Secretary of War and assented to by the Moline Water Power Company, with an agreement from said company that the expenditure of the sums hereby appropriated for continuing and completing the improvement of the water-power pool according to such plans and specifications, and also the deepening of said canal to an average depth of at least three feet at its present width, and also the placing of six openings for water wheels, according to such plans and specifications, will be accepted by the Moline Water Power Company in full discharge of the obligations of the United States to develop the water power; and provided, further, that the certificate of the commanding officer of the Rock Island Arsenal shall be conclusive evidence as to the required deepening of said canal and the placing of said openings for water wheels; and provided, further, that before the expenditure of any part of the appropriations hereby made for deepening said canal and the placing of said openings for water wheels, said Moline Water Power Company shall give to the Secretary of War satisfactory assurances and guarantees that it will complete the corresponding deepening of the tail race above said canal at the same time the deepening of said canal shall be completed. Therefore, the Moline Water Power Company hereby agrees and binds itself to deepen the tail race above the water-power canal to correspond with the deepening the United States shall make in said canal, provided for in the above act; and the Moline Water Power Company further agrees and binds itself, on condition and as a consideration that the United States expends the moneys hereinbefore named, or so much thereof as may be necessary to complete the work in making certain improvements of the water-power pool and of deepening the tail-race canal and of placing six openings for water wheels in the dyke for the free and unrestricted use in perpetuity of the Moline Water Power Co., its lessees, or assigns, under the same rules and contract obligations that govern the other openings for the use of the water-power company. The Moline Water Power Company hereby agrees to accept the above as a complete discharge of the obligation of the United States to develop the water power, and as a settlement and complete satisfaction of all claims of the Moline Water Power Company against the United States, leaving no further obligations of the United States to the Moline Water Power Company except that of maintaining the water power so developed; and the Moline Water Power Company further agrees that a certificate of the commanding officer at Rock Island Arsenal, that the work of deepening the canal and placing of said openings for water wheels in the dyke for the use of the Moline Water Power Company, and of continuing and completing the improvement of the water-power pool has been fully and properly performed, shall be conclusive evidence of its performance. And this, with the further expenditure of sums appropriated in the act for the improvement of the pool, shall be accepted and operate as a discharge of the obligations of the United States to the Moline Water Power Co. for the further development of the water power. The plans and specifications of the work to be done by the United States, mentioned above, are as follows:

1st. The United States shall deepen the water-power canal at least an average depth of three feet at its present width, and shall extend this deepening into the river at the west end of the canal until the new bottom of the canal, as determined by this deepening, shall reach a point in the river where the river bottom is as low as the new bottom of the canal, and shall extend said deepening into the tail race at the east end of the canal, until said deepening reaches the shore line of what was the natural bottom of the river at this point; and for performing this work the United States is to have the right to take earth from the water power company's land for the construction of coffer-dams, and is to have the rights and privileges granted under headings 1st of an agreement between the Water Power Company and the United States dated April 8, 1869.

2d. The United States shall remove a portion of the stone dyke between the water-power pool and the tail race, generally known as the stone dyke, and substitute therefor a good and substantial stone and cement mortar wall to have six openings or water-ways not less than eight and one-half feet wide, and about eight feet high, for the exclusive use of the Moline Water Power Company, its lessees or assigns. Said wall to have good and sufficient wing walls for sustaining the adjacent ends of the stone dyke; the opening to be provided with good iron gates with attachments for operating the same, practically the same as the iron gates the commanding officer of the Rock Island arsenal has placed at the openings in the other dams of the water power, the wall to be provided with good strong eyebolts for the attachment of the Water Power Company's forebays, or penstocks, the wing wall on the north side to be provided with other eyebolts for the attachment of strainers, and said wall and wing walls are to have the dimensions given in the drawing attached hereto marked D, and is to be located as near the west end of the stone dyke as is practicable, and have the west side of the west opening on the point A on the said drawing at the shore line of the natural bottom of the pool.

3d. The commanding officer of the Rock Island Arsenal shall use the moneys hereinbefore mentioned, to wit: The thirty thousand dollars for completing the improvement of the water-power pool and the unexpended balances of the appropriations for the same purpose of the years 1880 and 1881, or so much thereof as shall be required reappropriated in the aforementioned act, in making provision for and in washing and removing deposits out of the pool, in cutting a channel from the main river into the pool, and in extending the wing-dam not less than 300 feet up the river.

In testimony whereof this agreement has been signed by Robert T. Lincoln, Secretary of War, acting for and in behalf of the United States of America, and the seal of the War Department of the United States has been hereto affixed, and the Moline Water Power Company has, by a resolution of said company, duly passed in accordance with the by-laws, of which an attested copy is hereto attached, causes this agreement to be signed by Charles Atkinson, its president, and John M. Gould, its secretary, and its corporate seal to be hereto affixed on this 28th day of August, A. D. 1882.

[L. S.] CHARLES ATKINSON,
President.

J. M. GOULD,
Secretary.

[L. S.] ROBERT T. LINCOLN,
Secretary of War.

At a meeting of the board of directors of the Moline Water Power Company, held at Moline, Ill., August 28, 1882, the following resolution was unanimously adopted:

Resolved, That Charles Atkinson and John M. Gould, the president and secretary of this company, be, and they are hereby, authorized to sign, in behalf of the Moline Water Power Company, an agreement with the Secretary of War, for the purpose of carrying out so much of the provisions of the act making appropriations for sundry civil and other purposes of the Government, for the fiscal year ending June 30, 1883, as relates to the water power at Rock Island Arsenal, and to attach to said agreement the corporate seal of this company.

A true copy.

Attest:

(Sgd.) J. M. GOULD,
Secretary.

PLATE I

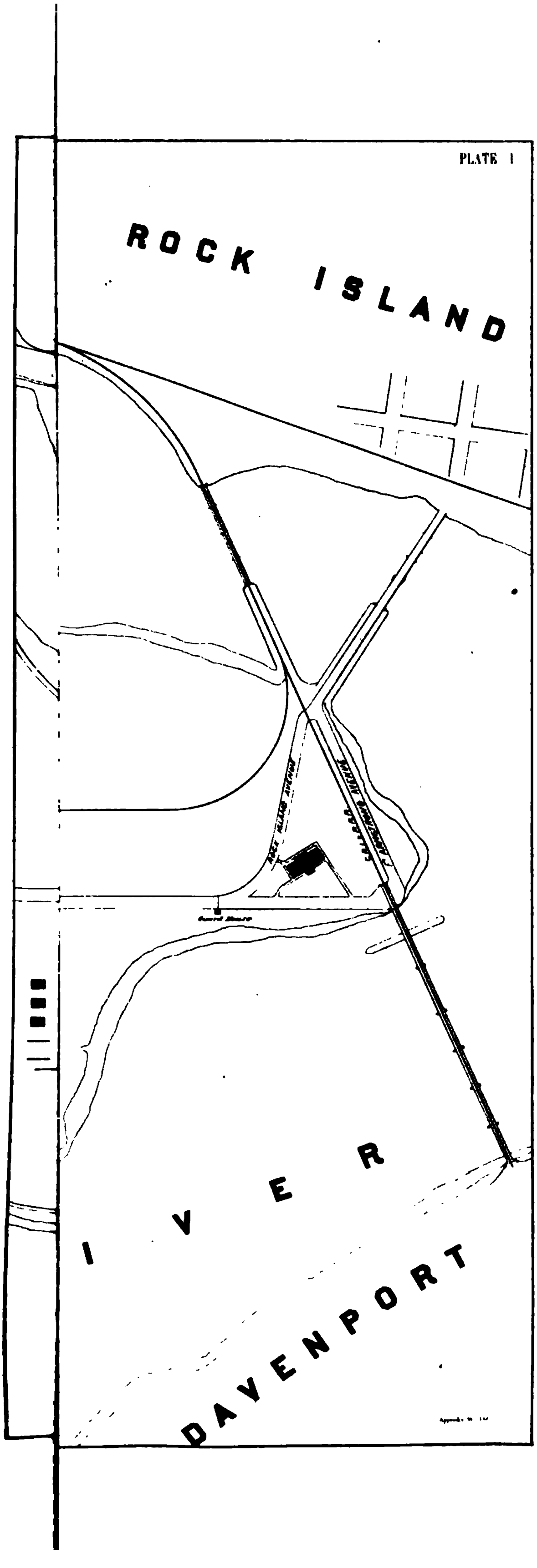


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PLATE III.

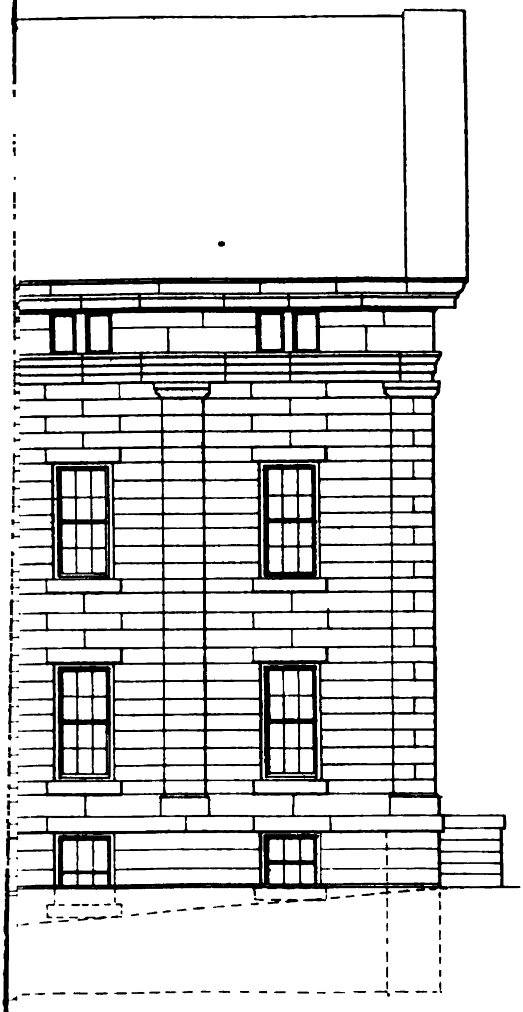
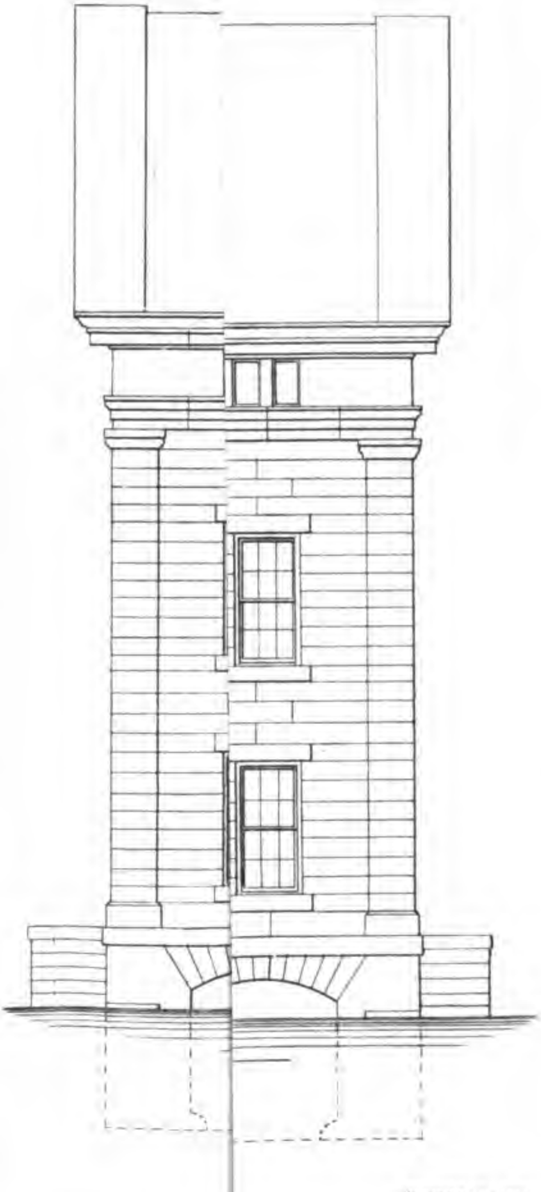


PLATE IV.



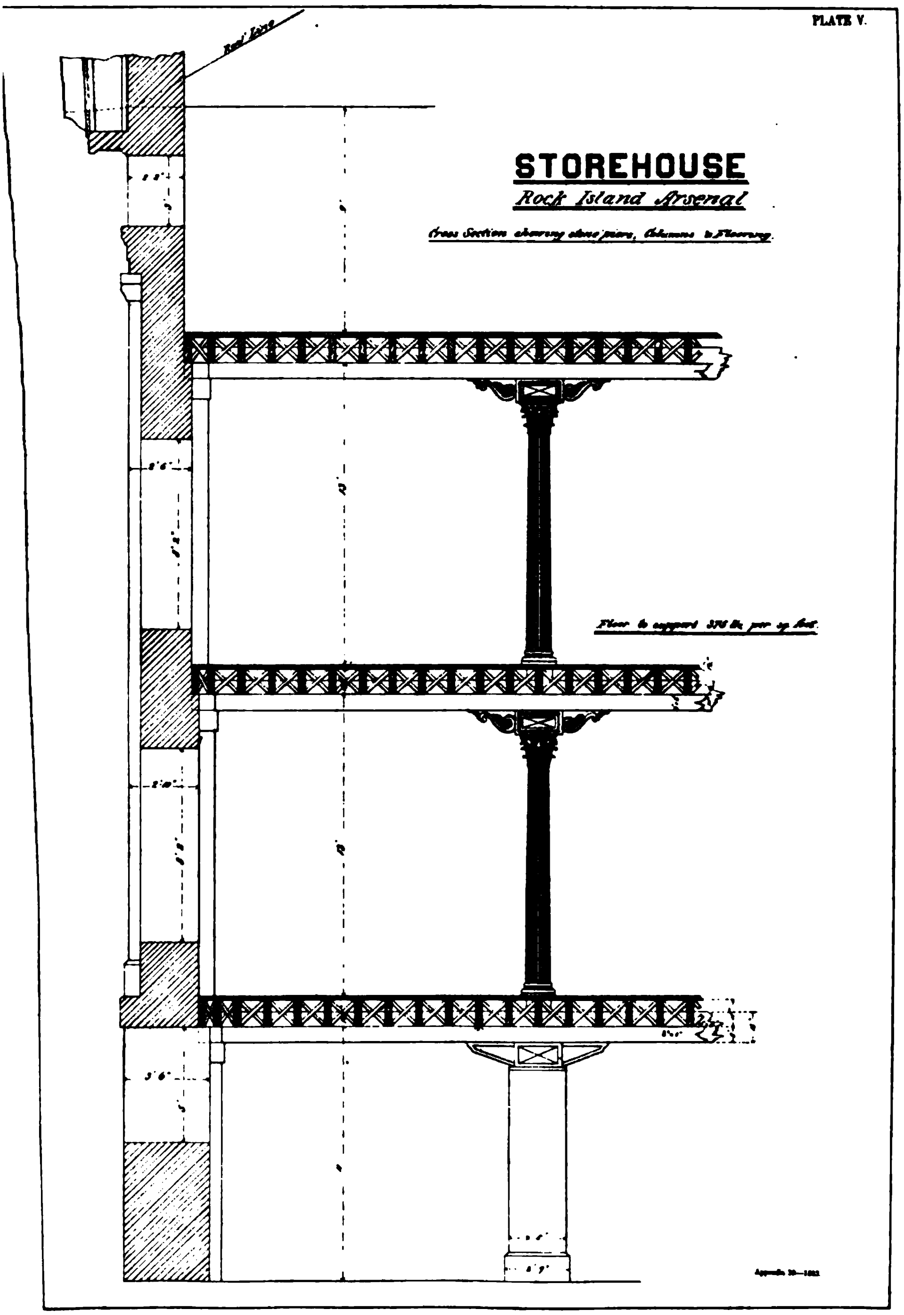
Appendix 38—1883.

PLATE V.

STOREHOUSE

Rock Island Arsenal

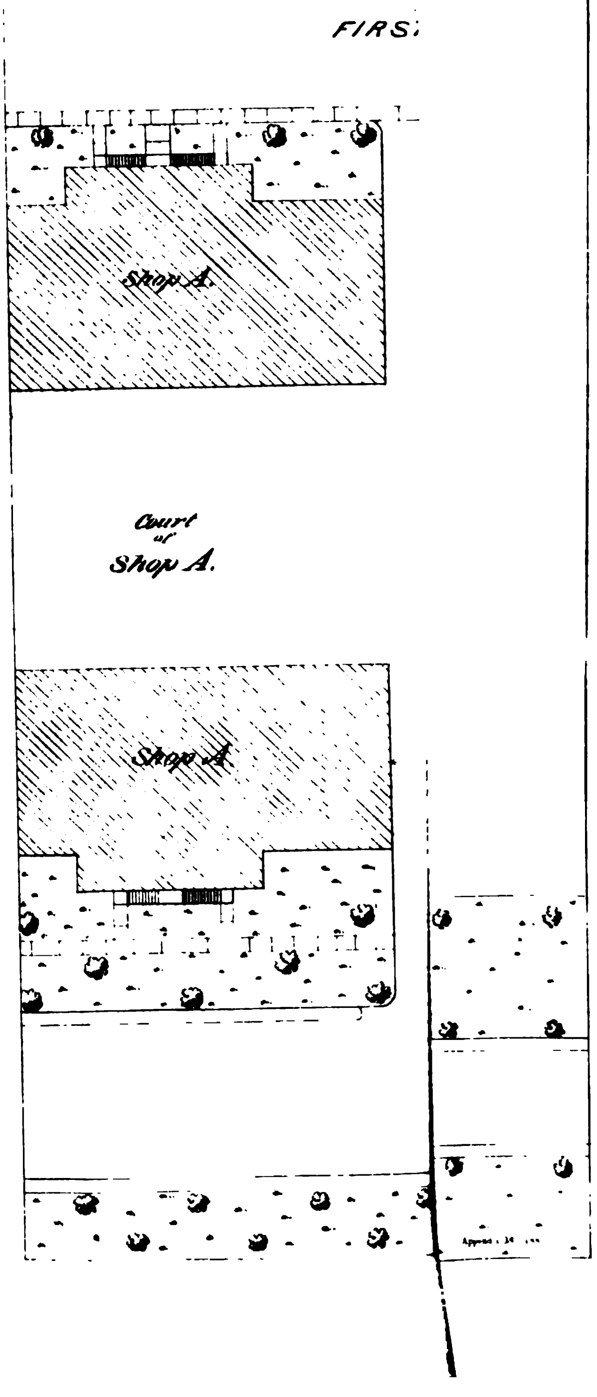
Cross Section showing stone piers, Columns & Flooring.



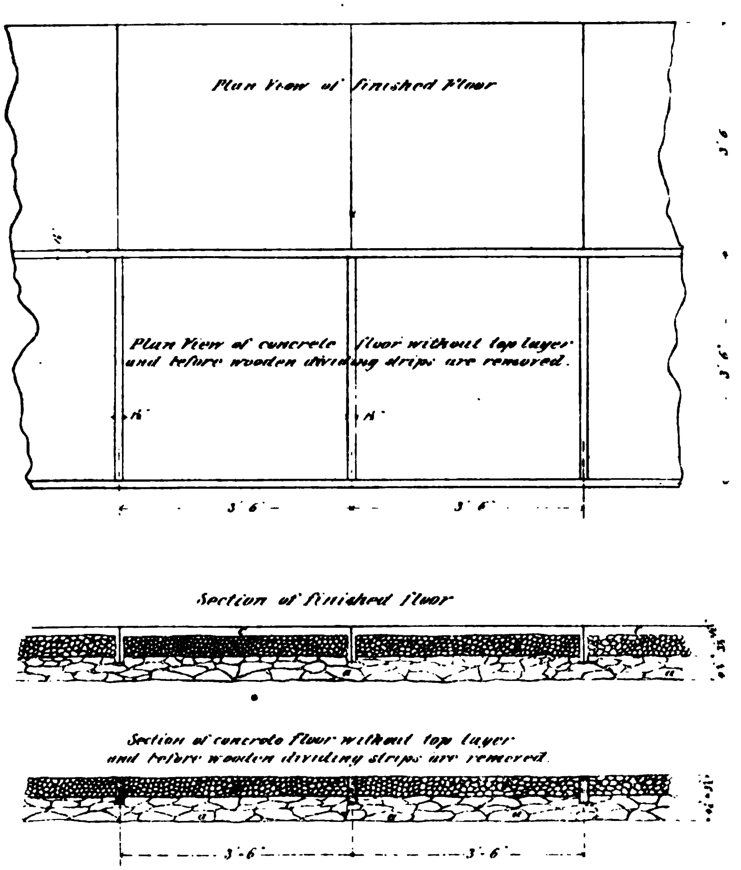
Appendix 39—1882

PLATE VI.

Plat showing arrangement



Concrete Floors & Walks.



Plan View of finished Floor

Plan View of concrete floor without top layer and before wooden dividing strips are removed.

Section of finished floor

Section of concrete floor without top layer and before wooden dividing strips are removed.

Legend

a Broken rock foundation
b Concrete.
c Top dressing of cement mortar

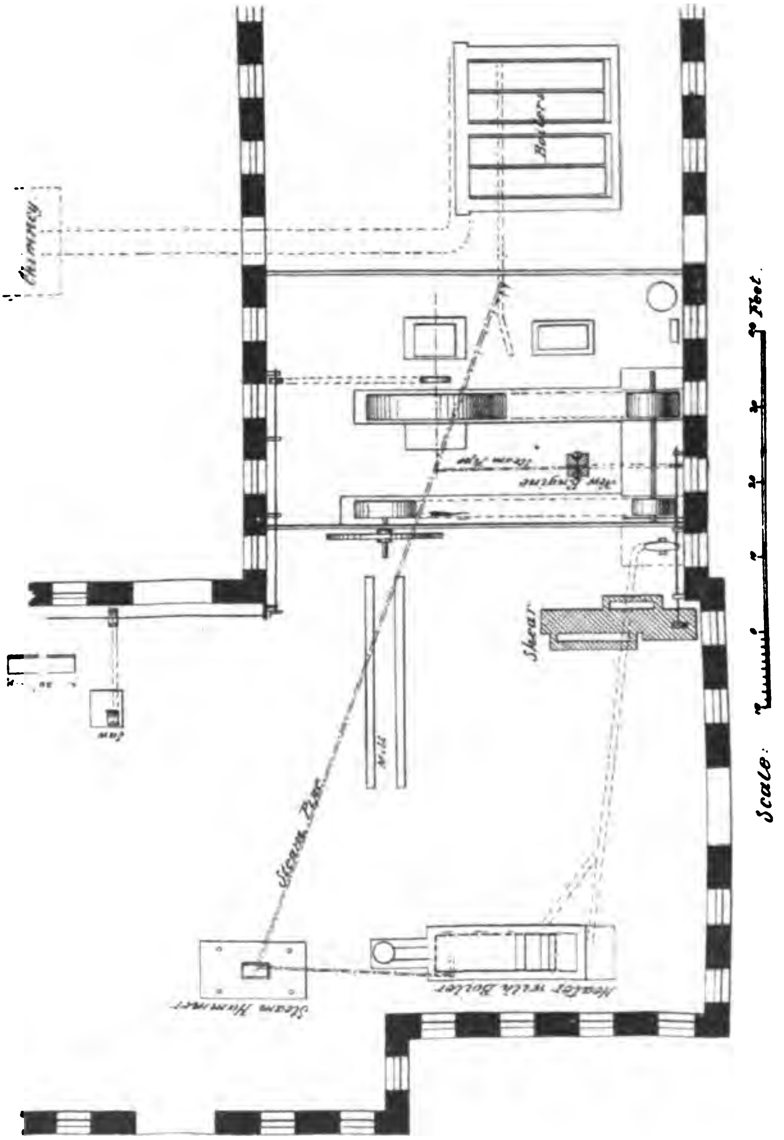
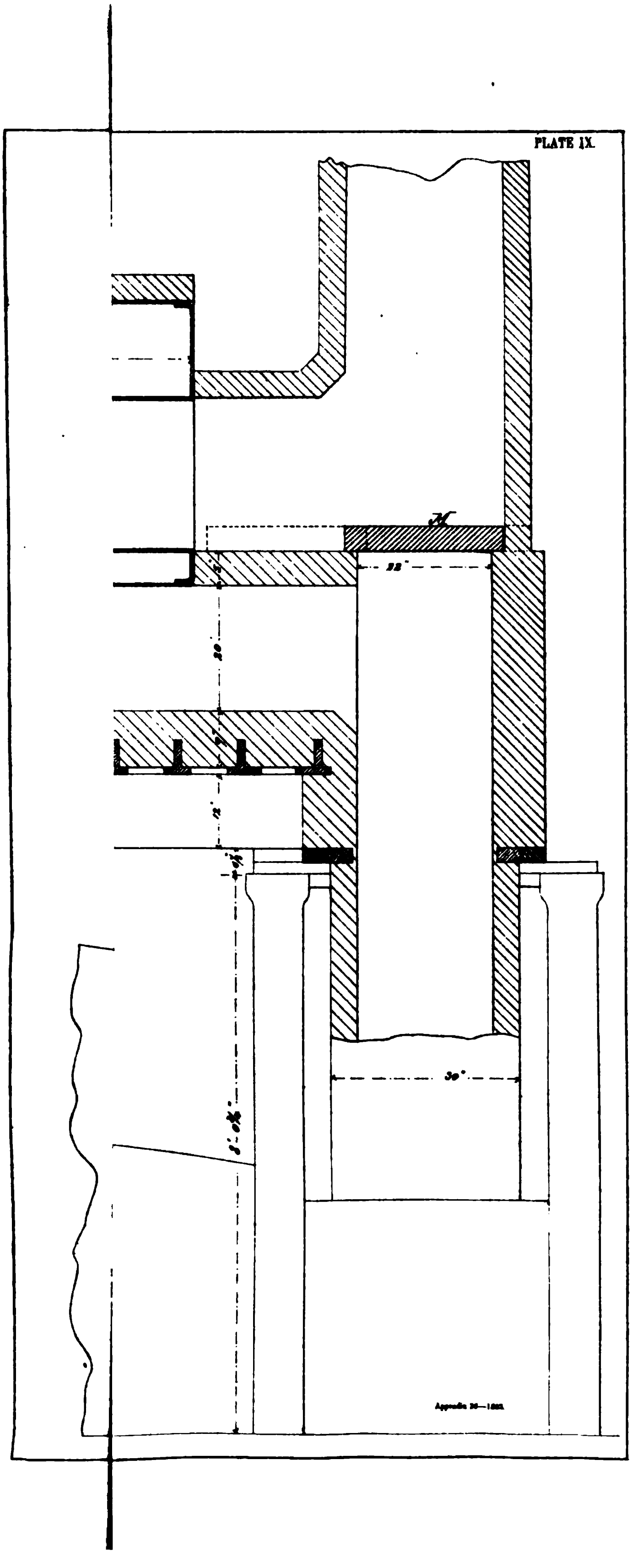

Chimney
Boilers
New Engine
Steam Pipe
Shear
Saw
Mill
Steam Pipe
Steam Hammer
Heater with Boiler
Scale:
10
0
10
20
30
40 Feet

PLATE IX.



Appendix 36—1882.

APPENDIX 39.

GUNS BEING MADE UNDER THE PROVISIONS OF ACT OF CONGRESS APPROVED MARCH 3, 1883.

(9 plates.)

1st. 10-inch Rodman smooth-bore guns converted into 8-inch rifles by lining with a coiled wrought-iron tube.
2d. 12-inch cast-iron breech-loading rifle.
3d. 12-inch cast-iron breech-loading rifle, lined with a wire-wrapped steel tube.
4th. 12-inch cast-iron muzzle-loading rifled mortar, banded with steel hoops.
5th. 10-inch cast-iron breech-loading rifle, wrapped with steel wire.
6th. 12-inch cast-iron breech-loading rifle, hooped and tubed with steel.
7th. 10-inch steel breech-loading rifle, wire wrapped.
8th. 8-inch breech-loading steel rifle, hooped.
9th. 8-inch steel breech-loading rifle, steel hooped, alternate drawing.

PLATE I.

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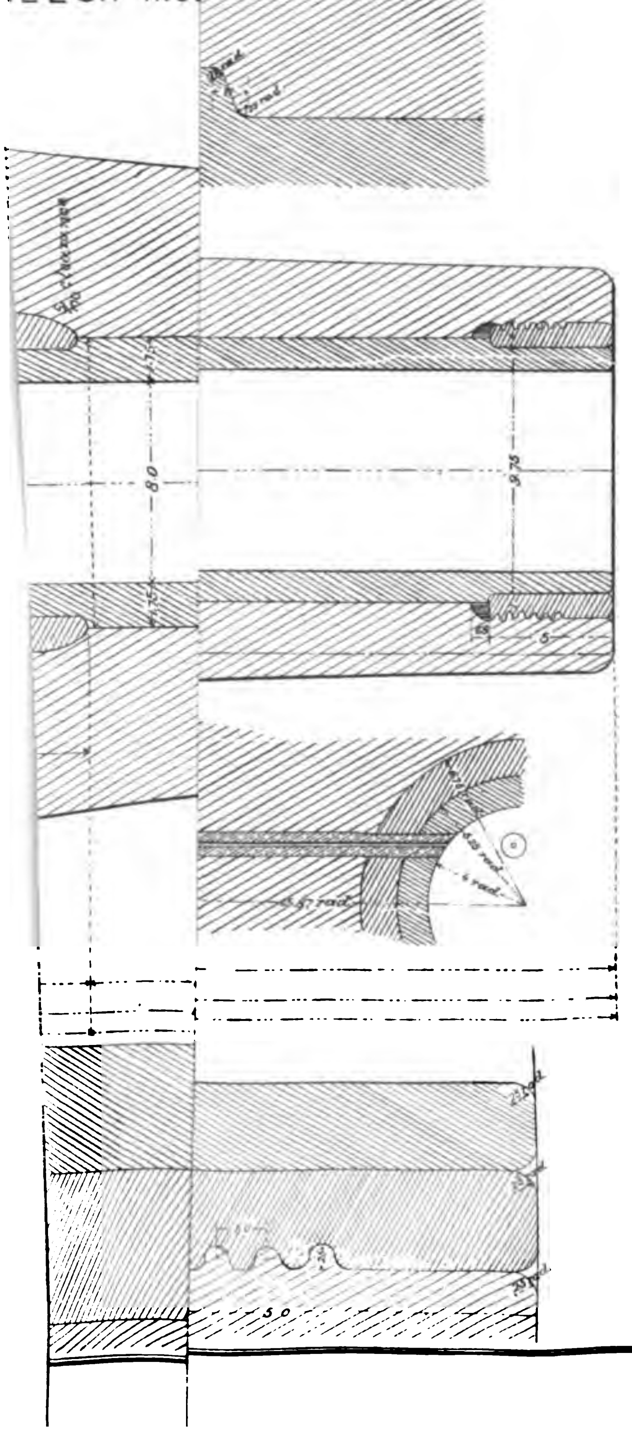
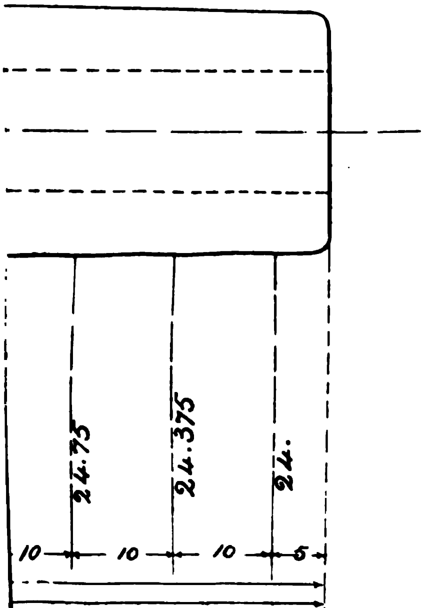


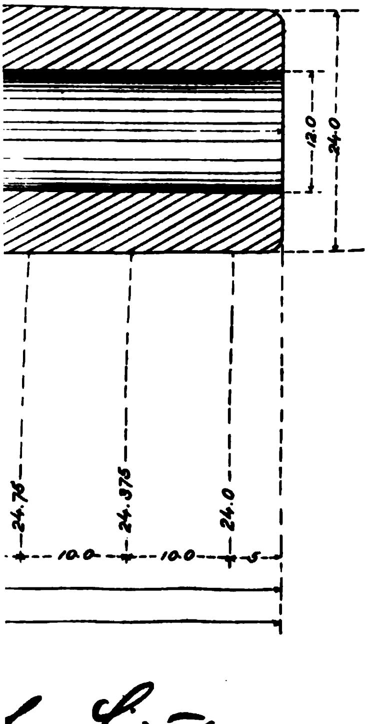
PLATE II.



Chas S. Smith
Captain of Ordnance.
Principal Asst. to Chief of Ordnance.

Appendix 39—1883.

PLATE III.



Smith.

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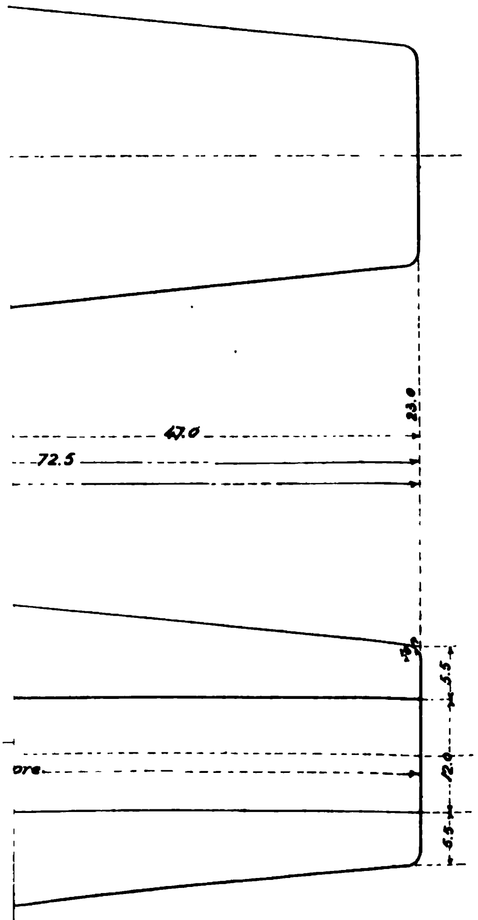


Chas S. Smith,

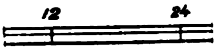
Capt. of Ordnance,
Principal Ass't to Chief of Ordnance.

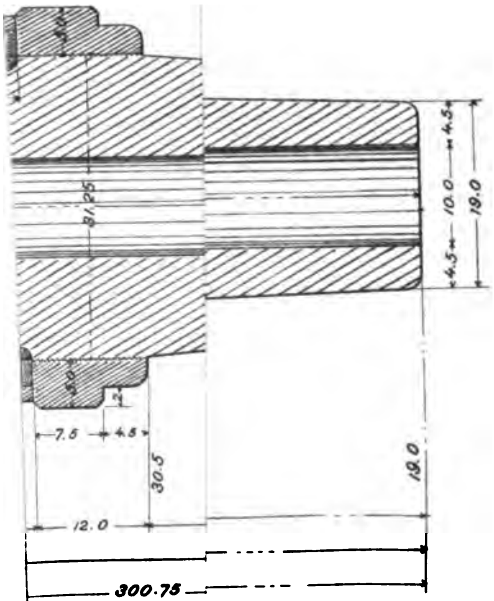
ndix 39—1883.

PLATE V.

D CAS

Scale:





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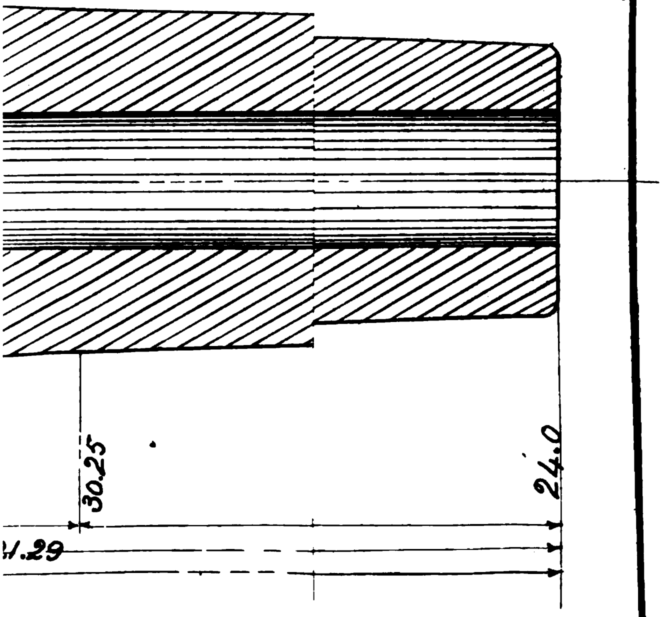
Appendix 39—1883.

PLATE VI.



nance.
sst, to Chief of Ordnance.

Appendix 39—1883.

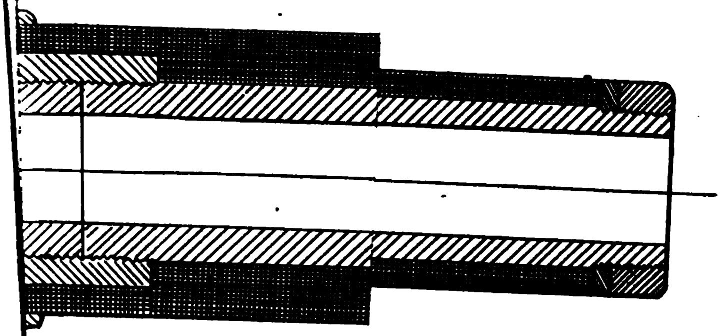
PLATE VII.

L BARS: WIRE-V

ldered.

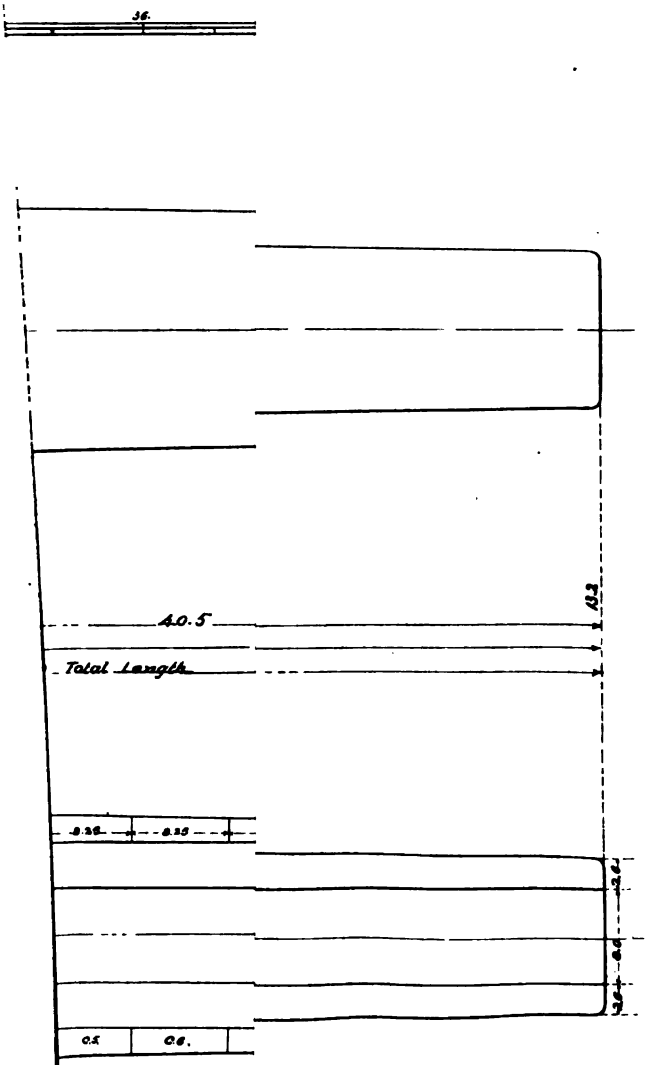
E. WOODBRIDGE.——

22 tons.
275 pounds.
450 .. " ..
150 feet per second.
18 tons per sq. inch.
00 tons.
22.35 inches
20.39 .. " ..



Appendix 39—1883.

LE -13 T



Chas. S. Smith.
Capt. of Ordnance.
cipal Asst. to Chief of Ordnance.

PLATE IX.

LE - 12½ TC

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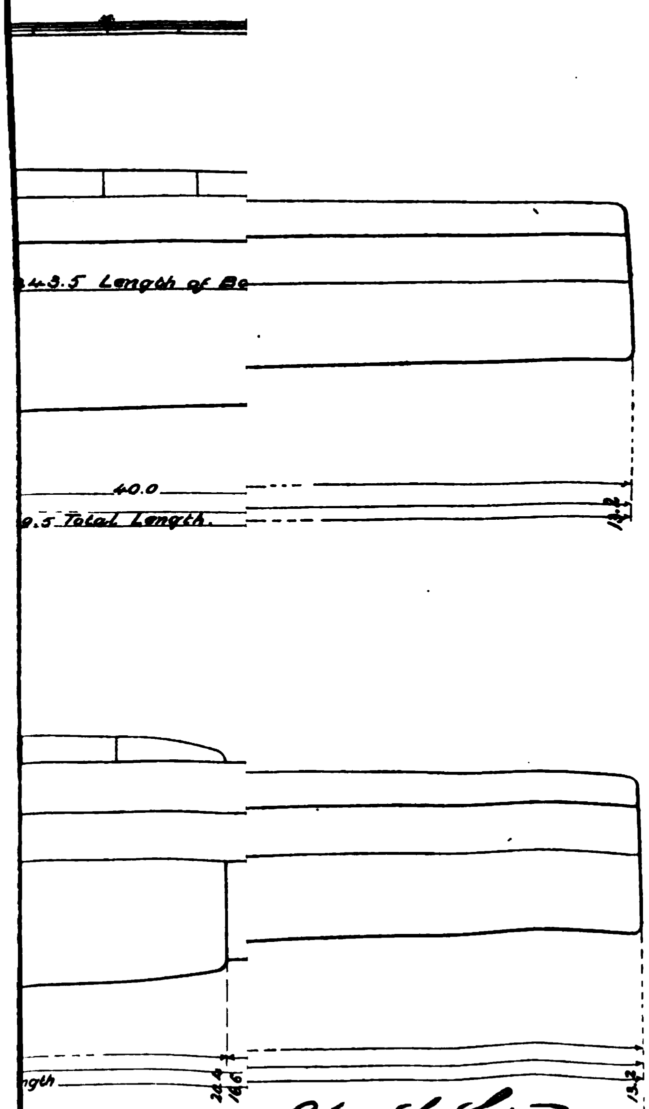

Chas. S. Smith.
Capt. of Ordnance
Principal Asst. to Chief of Ordnance.

APPENDIX 40,

IOWING STATIONS AND DUTIES OF THE OFFICERS OF THE ORDNANCE DEPARTMENT ON OCTOBER 1, 1883.

Rank and name.	Duty.	Address.
BRIGADIER-GENERAL.		
ephen V. Benét	Chief of Ordnance	Washington, D. C.
COLONELS.		
J. McAllister, brevet	Commanding the Benicia Arsenal	Benicia, Cal.
S. Crispin, brevet	Commanding the Ordnance Agency	Corner of Houston and Greene streets, New York. Post-office box 1811.
T. G. Baylor, brevet	Commanding the New York Arsenal, president of the Ordnance Board, and member of Board on Foundry for Heaviest Cannon, &c.	Governor's Island, New York City. Post-office box 1449.
LIEUTENANT-COLONELS.		
J. M. Whittemore	On duty in the office of the Chief of Ordnance.	Washington, D. C.
A. R. Buffington	Commanding the National Armory	Springfield, Mass.
D. W. Flagler, brevet	Commanding the Rock Island Arsenal.	Rock Island, Ill.
A. Mordecai, brevet	Commanding the Watervliet Arsenal	West Troy, N. Y.
MAJORS.		
S. C. Lyford, brevet lieutenant-colonel.	Commanding the Frankford Arsenal	Philadelphia, Pa.
2. F. H. Parker, brevet	Commanding the Watertown Arsenal.	Watertown, Mass.
3. J. P. Farley	Commanding the Piccatinny Powder Depot.	Dover, N. J.
4. L. S. Babbitt	Commanding the Fort Monroe Arsenal.	Fort Monroe, Va.
5. W. A. Marye	Commanding the Augusta Arsenal	Augusta, Ga.
6. I. Arnold, jr	Commanding the Indianapolis Arsenal.	Indianapolis, Ind.
7. C. Comly	Instructor of Ordnance and Gunnery. United States Military Academy.	West Point, N. Y.
8. J. R. McGinness, brevet	Commanding the Saint Louis Powder Depot.	Jefferson Barracks, Mo.
9. G. W. McKee, brevet	Member of the Ordnance Board	Governor's Island, New York City. Post-office box 1449.
0. F. H. Phipps, brevet	Commanding the Kennebec Arsenal.	Augusta, Me.
CAPTAINS.		
1. J. W. Reilly, brevet	Commanding the Allegheny Arsenal	Pittsburgh, Pa.
2. J. A. Kress, brevet major	Commanding the San Antonio Arsenal and Chief Ordnance Officer, Department of Texas.	San Antonio, Tex.
3. O. E. Michaelis, brevet	Assistant, Frankford Arsenal	Philadelphia, Pa.
4. C. E. Dutton	On duty under the Interior Department.	Geological Survey, Washington, D. C.
5. J. G. Butler	Assistant, Rock Island Arsenal	Rock Island, Ill.
6. C. Bryant	Commanding the Vancouver Barracks Ordnance Depot and Chief Ordnance Officer, Department of the Columbia.	Vancouver, Washington Territory.
7. A. L. Varney	Assistant, Watervliet Arsenal	West Troy, N. Y.
8. J. C. Clifford	do	Do.
9. J. E. Greer	Assistant, National Armory	Springfield, Mass.
0. J. Pitman	Assistant, Watertown Arsenal	Watertown, Mass.
1. C. Shaler	Member of the Ordnance Board	Governor's Island, New York City. Post-office box 1449.
2. H. Metcalfe	Assistant, Benicia Arsenal	Benicia, Cal.
3. W. S. Starring	Assistant to the Ordnance Board	Governor's Island, New York City. Post-office box 1449.

Stations and duties of the officers of the Ordnance Department, &c.—Continued.

Rank and name.	Duty.	Address.
CAPTAINS—Continued.		
14. C. S. Smith	Principal Assistant in the Ordnance Bureau.	Washington, D. C.
15. S. E. Blunt	Chief Ordnance Officer, Department of Dakota.	Fort Snelling, Minn.
16. F. Heath	Commanding the Cheyenne Ordnance Depot and Chief Ordnance Officer, Department of the Platte.	Cheyenne, Wyo.
17. D. M. Taylor, A. D. C	Commanding the Fort Leavenworth Ordnance Depot and Chief Ordnance Officer, Department of the Missouri.	Fort Leavenworth, Kans.
18. D. A. Lyle	On foundry duty, and member of the Board on Life-saving Apparatus, &c., under the Secretary of the Treasury.	Boston, Mass. Post-office box 2253.
19. J. Rockwell, jr	Commanding the Fort Abraham Lincoln Ordnance Depot.	Fort Abraham Lincoln, Dak
20. J. C. Ayres	Assistant, National Armory	Springfield, Mass.
FIRST LIEUTENANTS.		
1. M. W. Lyon	Assistant, Frankford Arsenal	Philadelphia, Pa.
2. C. W. Whipple	On foundry duty	Cold Spring, N. Y.
3. A. H. Russell	Assistant, Benicia Arsenal	Benicia, Cal.
4. R. Birnie, jr	Assistant, on foundry duty	Cold Spring, N. Y.
5. I. MacNutt	Assistant, Frankford Arsenal	Philadelphia, Pa.
6. C. C. Morrison	Assistant, Rock Island Arsenal	Rock Island, Ill.
7. F. Baker	Assistant, Watertown Arsenal	Watertown, Mass.
8. O. B. Mitcham	Assistant, Rock Island Arsenal	Rock Island, Ill.
9. H. D. Borup	Assistant, on foundry duty	Boston, Mass. Post-office box 2253.
10. L. L. Bruff	On sick leave	Easton, Md.
11. C. H. Clark	Assistant Instructor of Ordnance and Gunnery, United States Military Academy.	West Point, N. Y.
12. W. M. Medcalfe	On leave, abroad	
13. William Crozier	Acting Assistant Professor of Mathematics, United States Military Academy.	West Point, N. Y.
14. W. B. Gordon	Assistant, Watervliet Arsenal	West Troy, N. Y.
15. F. E. Hobbs	On foundry duty	Station G, Philadelphia, Pa
16. D. A. Howard	Acting Assistant Professor of Mathematics, United States Military Academy.	West Point, N. Y.
ORDNANCE STOREKEEPERS.		
A. S. M. Morgan, captain	On duty, Allegheny Arsenal	Pittsburgh, Pa.
W. H. Rexford, captain	On duty, Indianapolis Arsenal	Indianapolis, Ind.
D. J. Young, captain	On duty, Watervliet Arsenal	West Troy, N. Y.
M. J. Grealish, captain	On duty, Augusta Arsenal	Augusta, Ga.
V. McNally, captain	On duty in the office of the Chief of Ordnance.	Washington, D. C.

APPENDIX 41.

MECHANICAL TESTS OF SPECIMENS TAKEN FROM STEEL HOOPS FOR CANNON.

BY LIEUT. C. W. WHIPPLE, ORDNANCE DEPARTMENT.

UNITED STATES ORDNANCE PROVING GROUND,
Sandy Hook, N. J., October 5, 1883.

SIR: I have the honor to inclose herewith records of tests for mechanical properties of certain specimens taken from experimental hoops of Midvale steel, made in accordance with instructions from your office of various dates commencing July 10, 1883. The series will be completed as soon as possible. The records inclosed are as follows:

Four specimens from oil-tempered hoop marked *g*, 9018, 1, 2, 3, 4—3 inches between shoulders.

Four specimens from annealed hoop marked *g*, 9020, 1, 2, 3, 4—3 inches between shoulders.

One specimen from oil-tempered hoop marked *g*, 9018, 1—2 inches between shoulders.

One specimen from oil-tempered hoop marked *g*, 9018, 3—2 inches between shoulders.

One specimen from annealed hoop marked *g*, 9020, 1—2 inches between shoulders.

One specimen from annealed hoop marked *g*, 9020, 3—2 inches between shoulders.

One specimen from oil-tempered hoop marked *g*, 9018, 2—2 inches between shoulders, turned through a mistake in instructions, and consequently additional to the series proper. Parts of these broken specimens, numbered and marked on the side in order from 1 to 13, are to-day shipped to you by express.

Very respectfully, your obedient servant,

C. W. WHIPPLE,
Lieutenant of Ordnance.

The CHIEF OF ORDNANCE, U. S. A.

UNITED STATES ORDNANCE PROVING GROUND,
Sandy Hook, N. J., October 9, 1883.

SIR: I have the honor to inclose records of tests for mechanical properties of two specimens of Midvale steel, taken from an experimental hammered hoop. The half specimens have been shipped to you, stamped on the side 14 and 15, together with the specimens from oil-tempered and annealed hoops referred to in my letter of October 5, 1883. All these specimens will be ultimately tested for hardness and specific gravity.

Very respectfully, your obedient servant,

C. W. WHIPPLE,
Lieutenant of Ordnance.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

APPENDIX 40,

SHOWING STATIONS AND DUTIES OF THE OFFICERS OF THE ORDNANCE DEPARTMENT ON OCTOBER 1, 1883.

Rank and name.	Duty.	Address.
BRIGADIER-GENERAL.		
Stephen V. Benét	Chief of Ordnance	Washington, D. C.
COLONELS.		
1. J. McAllister, brevet	Commanding the Benicia Arsenal	Benicia, Cal.
2 S. Crispin, brevet	Commanding the Ordnance Agency	Corner of Houston and Greene streets, New York. Post-office box 1811.
3. T. G. Baylor, brevet	Commanding the New York Arsenal, president of the Ordnance Board, and member of Board on Foundry for Heaviest Cannon, &c.	Governor's Island, New York City. Post-office box 1449.
LIEUTENANT-COLONELS.		
1. J. M. Whittemore	On duty in the office of the Chief of Ordnance.	Washington, D. C.
2. A. R. Buffington	Commanding the National Armory	Springfield, Mass.
3. D. W. Flagler, brevet	Commanding the Rock Island Arsenal.	Rock Island, Ill.
4. A. Mordecai, brevet	Commanding the Watervliet Arsenal	West Troy, N. Y.
MAJORS.		
1. S. C. Lyford, brevet lieutenant-colonel.	Commanding the Frankford Arsenal	Philadelphia, Pa.
2. F. H. Parker, brevet	Commanding the Watertown Arsenal.	Watertown, Mass.
3. J. P. Farley	Commanding the Piccatinny Powder Depot.	Dover, N. J.
4. L. S. Babbitt	Commanding the Fort Monroe Arsenal.	Fort Monroe, Va.
5. W. A. Marye	Commanding the Augusta Arsenal	Augusta, Ga.
6. I. Arnold, jr	Commanding the Indianapolis Arsenal.	Indianapolis, Ind.
7. C. Comly	Instructor of Ordnance and Gunnery. United States Military Academy.	West Point, N. Y.
8. J. R. McGinness, brevet	Commanding the Saint Louis Powder Depot.	Jefferson Barracks, Mo.
9. G. W. McKee, brevet	Member of the Ordnance Board	Governor's Island. New York City. Post-office box 1449.
10. F. H. Phipps, brevet	Commanding the Kennebec Arsenal.	Augusta, Me.
CAPTAINS.		
1. J. W. Reilly, brevet	Commanding the Allegheny Arsenal	Pittsburgh, Pa.
2. J. A. Kress, brevet major	Commanding the San Antonio Arsenal and Chief Ordnance Officer, Department of Texas.	San Antonio, Tex.
3. O. E. Michaelis, brevet	Assistant, Frankford Arsenal	Philadelphia, Pa.
4. C. E. Dutton	On duty under the Interior Department.	Geological Survey, Washington, D. C.
5. J. G. Butler	Assistant, Rock Island Arsenal	Rock Island, Ill.
6. C. Bryant	Commanding the Vancouver Barracks Ordnance Depot and Chief Ordnance Officer, Department of the Columbia.	Vancouver, Washington Territory.
7. A. L. Varney	Assistant, Watervliet Arsenal	West Troy, N. Y.
8. J. C. Clifford	do	Do.
9. J. E. Greer	Assistant, National Armory	Springfield, Mass.
10. J. Pitman	Assistant, Watertown Arsenal	Watertown, Mass.
11. C. Shaler	Member of the Ordnance Board	Governor's Island, New York City. Post-office box 1449.
12. H. Metcalfe	Assistant, Benicia Arsenal	Benicia, Cal.
13. W. S. Starring	Assistant to the Ordnance Board	Governor's Island, New York City. Post-office box 1449.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
43, 000	.002333	.000000	.002333	.000000	....	....
44, 000	.002333	.000000	.002333	.000000	....	....
45, 000	.002333	.000000	.002333	.000000	....	....
46, 000	.002333	.000000	.002333	.000000	....	....
47, 000	.002333	.000000	.002333	.000000	....	....
48, 000	.002333	.000000	.002333	.000000	....	....
49, 000	.002666	.000333	.002666	.000333	....	....
50, 000	.002666	.000000	.002666	.000000	....	....
51, 000	.002666	.000000	.002666	.000000	....	....
52, 000	.002666	.000000	.002666	.000000	....	....
53, 000	.003000	.000334	.003000	.000334	....	....
54, 000	.003000	.000000	.003000	.000000	....	....
55, 000	.003000	.000000	.000666	—.002334	.000666	.000666
56, 000	.003666	.000666	.001000	.000334	.001000	.000334
57, 000	.004000	.000334	.001000	.000000	.001000	.000000
58, 000	.004000	.000000	.001333	.000333	.001333	.000333
59, 000	.004333	.000333	.001666	.000333	.001666	.000333
60, 000	.004333	.000000	.002000	.001334	.002000	.000334
61, 000	.004333	.000000	.002333	.000333	.002000	.000000
62, 000	.004333	.000000	.002333	.000000	.002000	.000000
63, 000	.004666	.000333	.002333	.000000	.002333	.000333
64, 000	.004666	.000000	.002000	—.000333	.002666	.000333
65, 000	.005333	.000667	.001333	—.000667	.004000	.001334
66, 000	.006333	.001000	.002000	.000667	.004333	.000333
67, 000	.008000	.000667	.002000	.000000	.006000	.001667
68, 000	.009333	.001333	.002333	.000333	.007000	.001000
69, 000	.009666	.000333	.002666	.000333	.007000	.000000
70, 000	.010000	.000334	.002333	—.000333	.007666	.000666
71, 000	.010666	.000666	.002333	.000000	.008333	.000667
72, 000	.011333	.000667	.002333	.000000	.009000	.000667
73, 000	.012666	.001333	.002333	.000000	.010333	.001333
74, 000	.013666	.001000	.002000	—.000333	.011666	.001333
75, 000	.015000	.001334	.003000	.001000	.012000	.000334
76, 000	.015666	.000666	.003000	.000000	.012666	.000666
77, 000	.017000	.001334	.002000	—.001000	.015000	.002334
78, 000	.018000	.001000	.002333	.000333	.015666	.000666
79, 000	.018666	.000666	.002666	.000333	.016000	.000334
80, 000	.020333	.001667	.003333	.000667	.017000	.001000
81, 000	.021666	.001333	.003666	.000333	.018000	.001000
82, 000	.022666	.001000	.003666	.000000	.019000	.001000
83, 000	.023000	.000334	.002666	—.001000	.020333	.001333
84, 000	.024333	.001333	.003000	.000334	.021333	.001000
85, 000	.025333	.001000	.003000	.000000	.022333	.001000
86, 000	.027000	.001667	.003000	.000000	.024000	.001667
87, 000	.028000	.001000	.003000	.000000	.025000	.001000
88, 000	.030000	.002000	.003333	.000333	.026666	.001666
89, 000	.032000	.002000	.003333	.000000	.028666	.002000
90, 000	.033666	.001666	.003333	.000000	.030333	.001667
91, 000	.035333	.001667	.003333	.000000	.032000	.001667
92, 000	.038000	.002667	.003666	.000333	.034333	.002333
93, 000	.040333	.002333	.003333	—.000333	.037000	.002667
94, 000	.043000	.002667	.003333	.000000	.039666	.002666
95, 000	.046000	.003000	.003666	.000333	.042333	.002667
96, 000	.049000	.003000	.004000	.000334	.045000	.002667
97, 000	.051666	.002666	.003666	—.000334	.048000	.003000
98, 000	.057666	.006000	.004333	.000667	.053333	.005333
99, 000	.063000	.005334	.004000	—.000333	.059000	.005667
100, 000	.071000	.008000	.004333	.000333	.066666	.007666
101, 000	.079000	.008000	.004333	.000000	.074666	.008000
102, 000	.090000	.011000	.004666	+.000333	.085333	.010667
103, 000	.113666	.023666	.004333	—.000333	.109333	.024000
104, 000	.181333	.067667	....	....	....	....

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds	*104, 000*
Elastic limit	do	54, 000
Extension per inch at rupture	inches	18. 13
Hardness		
Reduction in diameter at point of rupture	inch	0. 122
Original area of cross-section	square inch	0. 2463
Area after rupture	do	0. 1507
Position of rupture		near middle.
Character of surface		crystalline, with a dull gray core.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 3 inches long and 0.561 inch in diameter, taken from rolled hoop, oil-tempered and annealed.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1, 000	0. 000000	0. 000000	0. 000000	0. 000000	0. 000000	0. 000000
2, 000	. 000333	. 000333	. 000333	. 000333	. 000000	. 000000
3, 000	. 000333	. 000000	. 000333	. 000000	. 000000	. 000000
4, 000	000666	. 000333	. 000666	. 000333	. 000000	. 000000
5, 000	. 000666	. 000000	. 000666	. 000000	. 000000	. 000000
6, 000	. 000666	. 000000	. 000666	. 000000	. 000000	. 000000
7, 000	. 000666	. 000000	. 000666	. 000000	. 000000	. 000000
8, 000	. 001000	. 000334	. 001000	. 000334	. 000000	. 000000
9, 000	. 001000	. 000000	. 001000	. 000000	. 000000	. 000000
10, 000	. 001000	. 000000	. 001000	. 000000	. 000000	. 000000
11, 000	. 001000	. 000000	. 001000	. 000000	. 000000	. 000000
12, 000	. 001000	. 000000	. 001000	. 000000	. 000000	. 000000
13, 000	. 001000	. 000000	. 001000	. 000000	. 000000	. 000000
14, 000	. 001000	. 000000	. 001000	. 000000	. 000000	. 000000
15, 000	. 001333	. 000333	. 001333	. 000333	. 000000	. 000000
16, 000	. 001333	. 000000	. 001333	. 000000	. 000000	. 000000
17, 000	. 001333	. 000000	. 001333	. 000000	. 000000	. 000000
18, 000	. 001333	. 000000	. 001333	. 000000	. 000000	. 000000
19, 000	. 001666	. 000333	. 001666	. 000333	. 000000	. 000000
20, 000	. 001666	. 000000	. 001666	. 000000	. 000000	. 000000
21, 000	. 001666	. 000000	. 001666	. 000000	. 000000	. 000000
22, 000	. 001666	. 000000	. 001666	. 000000	. 000000	. 000000
23, 000	. 001666	. 000000	. 001666	. 000000	. 000000	. 000000
24, 000	. 001666	. 000000	. 001666	. 000000	. 000000	. 000000
25, 000	. 001666	. 000000	. 001666	. 000000	. 000000	. 000000
26, 000	. 001666	. 000000	. 001666	. 000000	. 000000	. 000000
27, 000	. 002000	. 000334	. 002000	. 000334	. 000000	. 000000
28, 000	. 002000	. 000000	. 002000	. 000000	. 000000	. 000000
29, 000	. 002000	. 000000	. 002000	. 000000	. 000000	. 000000
30, 000	. 002000	. 000000	. 002000	. 000000	. 000000	. 000000
31, 000	. 002000	. 000000	. 002000	. 000000	. 000000	. 000000
32, 000	. 002000	. 000000	. 002000	. 000000	. 000000	. 000000
33, 000	. 002333	. 000333	. 002333	. 000333	. 000000	. 000000
34, 000	. 002333	. 000000	. 002333	. 000000	. 000000	. 000000
35, 000	. 002333	. 000000	. 002333	. 000000	. 000000	. 000000
36, 000	. 002333	. 000000	. 002333	. 000000	. 000000	. 000000
37, 000	. 002333	. 000000	. 002333	. 000000	. 000000	. 000000
38, 000	. 002333	. 000000	. 002333	. 000000	. 000000	. 000000
39, 000	. 002666	. 000333	. 002666	. 000333	. 000000	. 000000
40, 000	. 002666	. 000000	. 002666	. 000000	. 000000	. 000000
41, 000	. 002666	. 000000	. 002666	. 000000	. 000000	. 000000
42, 000	. 002666	. 000000	. 002666	. 000000	. 000000	. 000000
43, 000	. 002666	. 000000	. 002666	. 000000	. 000000	. 000000
44, 000	. 002666	. 000000	. 002666	. 000000	. 000000	. 000000
45, 000	. 002666	. 000000	. 002666	. 000000	. 000000	. 000000
46, 000	. 002666	. 000000	. 002666	. 000000	. 000000	. 000000
47, 000	. 003000	. 000334	. 003000	. 000334	. 000000	. 000000
48, 000	. 003000	. 000000	. 003000	. 000000	. 000000	. 000000
49, 000	. 003000	. 000000	. 003000	. 000000	. 000000	. 000000
50, 000	. 003000	. 000000	. 003000	. 000000	. 000000	. 000000
51, 000	. 003000	. 000000	. 003000	. 000000	. 000000	. 000000
52, 000	. 003000	. 000000	. 003000	. 000000	. 000000	. 000000
53, 000	. 003333	. 000333	. 003333	. 000333	. 000000	. 000000
54, 000	. 003333	. 000000	. 003333	. 000000	. 000000	. 000000
55, 000	. 003333	. 000000	. 003333	. 000000	. 000000	. 000000
56, 000	. 003333	. 000000	. 003000	— . 000333	. 000333	. 000333
57, 000	. 003333	. 000000	. 003000	. 000000	. 000333	. 000000
58, 000	. 004000	. 001000	. 003333	. 000333	. 000666	. 000333
59, 000	. 004333	. 000333	. 003333	. 000000	. 001000	. 000334
60, 000	. 004333	. 000000	. 003000	— . 000333	. 001333	. 000333
61, 000	. 004666	. 000333	. 003333	. 000333	. 001333	. 000000
62, 000	. 004666	. 000000	. 003000	— . 000333	. 001666	. 000333
63, 000	. 005000	. 000334	. 003333	. 000333	. 001666	000000
64, 000	. 005000	. 000000	. 003333	. 000000	. 001666	. 000000
65, 000	. 005333	. 000333	. 003333	. 000000	. 002000	. 000334
66, 000	. 005666	. 000333	. 003333	. 000000	. 002333	. 000333
67, 000	. 006333	. 000667	. 003000	— . 000333	. 003333	. 001000
68, 000	. 007666	. 001333	. 003000	. 000000	. 004666	. 001333
69, 000	. 008666	. 001000	. 003000	. 000000	. 005666	. 001000
70, 000	. 009666	. 001000	. 003000	. 000000	. 006666	. 001000
71, 000	. 010333	. 000667	. 002666	— . 000334	. 007666	. 001000
72, 000	. 011333	. 001000	. 003000	. 000334	. 008333	. 000667
73, 000	. 012333	. 001000	. 003333	. 000333	. 009000	. 000667
74, 000	. 013000	. 000667	. 003333	. 000000	. 009666	. 000666
75, 000	. 014333	. 001333	. 003666	. 000333	. 010666	. 001000
76, 000	. 015000	. 000667	. 003333	— . 000333	. 011666	. 001000
77, 000	. 016000	. 001000	. 003333	. 000000	. 012666	. 001000

the extension, restoration, and permanent set, &c.—Continued.

ion h in h.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
-	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
00	.001000	.003333	.000000	.013666	.001000
66	.000666	.003333	.000000	.014333	.000667
66	.001000	.003000	— .000333	.015666	.001333
66	.002000	.003333	.000333	.017333	.001667
33	.001667	.003666	.000333	.018666	.001333
33	.001000	.003666	.000000	.019666	.001000
66	.001333	.003333	— .000333	.021333	.001667
00	.001334	.003333	.000000	.022666	.001333
33	.001333	.003666	.000333	.023666	.001000
00	.001667	.003666	.000000	.025333	.001667
00	.002000	.003666	.000000	.027333	.002000
66	.001666	.004000	.000334	.028666	.001333
66	.002000	.004000	.000000	.030666	.002000
66	.002000	.004333	.000333	.032333	.001667
33	.001667	.004333	.000000	.034000	.001667
00	.001667	.004333	.000000	.035666	.001666
66	.004666	.004000	— .000333	.040666	.005000
36	.002000	.004000	.000000	.042666	.002000
33	.002667	.004000	.000000	.045333	.002667
33	.004000	.004000	.000000	.049333	.004000
00	.002667	.003666	— .000334	.052333	.003000
66	.007666	.004000	.000334	.059666	.007333
33	.009667	.004066	.000666	.068666	.009000
00	.010667	.005000	.000334	.079000	.010334
00	.016000	.004666	— .000334	.095333	.015333
00	.083000	....	....	....	....

GENERAL SUMMARY.

....

are inch .... pounds.. 103,00

.... do.... 35,00

pture .... inch.. 0.185

....

t point of rupture .... inch.. 0.141

ction .... square inch.. 0.247

.... do... 0.135

.... near middle

.... crystalline, with core of rather loose dark gray structure

ension, restoration, and permanent set caused by the under-mentioned
nch of the primitive section acting upon a solid cylinder 3 inches long
ameter, taken from rolled hoop, oil-tempered and annealed.

ion h in h.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
00	0.000000	0.000000	0.000000	....	....
00	.000000	.000000	.000000	....	....
00	.000000	.000000	.000000	....	....
00	.000000	.000000	.000000	....	....
33	.000333	.000333	.000333	....	....
33	.000000	.000333	.000000	....	....
33	.000000	.000333	.000000	....	....
33	.000000	.000333	.000000	....	....
33	.000000	.000333	.000000	....	....
33	.000000	.000333	.000000	....	....
33	.000000	.000333	.000000	....	....
66	.000333	.000666	.000333	....	....
66	.000000	.000666	.000000	....	....
66	.000000	.000666	.000000	....	....
66	.000000	.000666	.000000	....	....
66	.000000	.000666	.000000	....	....
66	.000000	.000666	.000000	....	....
66	.000000	.000666	.000000	....	....
66	.000000	.000666	.000000	....	....
00	.000334	.001000	.000334	....	....
00	.000000	.001000	.000000	....	....
00	.000000	.001000	.000000	....	....
20	.000000	.001000	.000000	....	....
00	.000000	.001000	.000000	....	....
00	.000000	.001000	.000000	....	....

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
41,000	.001000	.000000	.001000	.000000	....	....
42,000	.001000	.000000	.001000	.000000	....	....
43,000	.001000	.000000	.001000	.000000	....	....
44,000	.001000	.000000	.001000	.000000	....	....
45,000	.001333	.000333	.001333	.000333	....	....
46,000	.001333	.000000	.001333	.000000	....	....
47,000	.001333	.000000	.001333	.000000	....	....
48,000	.001333	.000000	.001333	.000000	....	....
49,000	.001333	.000000	.001333	.000000	....	....
50,000	.001333	.000000	.001333	.000000	....	....
51,000	.001333	.000000	.001333	.000000	....	....
52,000	.001333	.000000	.001333	.000000	....	....
53,000	.001333	.000000	.001333	.000000	....	....
54,000	.001333	.000000	.001333	.000000	....	....
55,000	.001666	.000333	.001666	.000333	....	....
56,000	.001666	.000000	.001666	.000000	....	....
57,000	.001666	.000000	.001666	.000000	....	....
58,000	.001666	.000000	.001666	.000000	....	....
59,000	.001666	.000000	.001666	.000000	....	....
60,000	.001666	.001666	.001666	.000000	....	....
61,000	.001666	.001666	.001666	.000000	....	....
62,000	.002000	.000334	.002000	.000334	....	....
63,000	.002666	.000666	.002000	.000000	.000666	.000666
64,000	.003000	.000334	.002000	.000000	.001000	.000334
65,000	.004333	.001333	.002333	.000333	.002000	.001000
66,000	.004666	.000333	.002000	—.000333	.002666	.000666
67,000	.005666	.001000	.002000	.000000	.003666	.001000
68,000	.006000	.000334	.002333	.000333	.003666	.000000
69,000	.007666	.001666	.002666	.000333	.005000	.001334
70,000	.009000	.001334	.003000	.000334	.006000	.001000
71,000	.009666	.000666	.002666	—.000334	.007000	.001000
72,000	.010000	.000334	.002666	.000000	.008000	.001000
73,000	.011333	.001333	.002666	.000000	.008666	.000666
74,000	.012000	.000667	.003000	.000334	.009000	.000334
75,000	.012666	.000666	.003000	.000000	.009666	.000666
76,000	.013333	.000667	.003000	.000000	.010333	.000667
77,000	.014333	.001000	.003000	.000000	.011333	.001000
78,000	.016000	.001667	.003333	.000333	.012666	.001333
79,000	.017333	.001333	.003333	.000000	.014000	.001334
80,000	.017666	.000333	.003000	—.000333	.014666	.000666
81,000	.019333	.001667	.003000	.000000	.016333	.001667
82,000	.020666	.001333	.003333	.000333	.017333	.001000
83,000	.022333	.001667	.003333	.000000	.019000	.001667
84,000	.024000	.001667	.003333	.000000	.020666	.001666
85,000	.025000	.001000	.003666	.000333	.021333	.000667
86,000	.026666	.001666	.003666	.000000	.023000	.001667
87,000	.028000	.001334	.003666	.000000	.024333	.001333
88,000	.029333	.001333	.003666	.000000	.025666	.001333
89,000	.032333	.003000	.004000	.000334	.028333	.002667
90,000	.034333	.002000	.003666	—.000334	.030666	.002333
91,000	.036333	.002000	.003333	—.000333	.033000	.002334
92,000	.039000	.002667	.004333	.001000	.034666	.001666
93,000	.042333	.003333	.004000	—.000333	.038333	.003667
94,000	.045666	.003333	.004000	.000000	.041666	.003333
95,000	.050000	.004334	.004333	.000333	.045666	.004000
96,000	.054666	.004666	.004666	.000333	.050000	.004334
97,000	.060000	.005334	.004333	—.000333	.055666	.005666
98,000	.068000	.008000	.004666	.000333	.063333	.007667
99,000	.075333	.007333	.004666	.000000	.070666	.007333
100,000	.089000	.013667	.005333	.000667	.083666	.013000
101,000	.185666	.096666	....	....	....	....
102,000	....	....	....	....	....	....
103,000	....	....	....	....	....	....
104,000	....	....	....	....	....	....

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds..	101,000
Elastic limit	do....	68,000
Extension per inch at rupture	inches..	18.56
Hardness		
Reduction in diameter at point of rupture	inch..	0.154
Original area of cross-section	sq. inch..	0.2472
Area after rupture	do....	0.1301
Position of rupture		near middle.
Character of surface		uniform, but rather coarse fibrous structure.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 2 inches long and 0.565 inch in diameter, taken from rolled hoop, oil-tempered and annealed.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1, 000	0. 000000	0. 000000	0. 000000	0. 000000	....	....
2, 000	. 000000	. 000000	. 000000	. 000000	....	....
3, 000	. 000000	. 000000	. 000000	. 000000	....	....
4, 000	. 000000	. 000000	. 000000	. 000000	....	....
5, 000	. 000500	. 000500	. 000500	. 000500	....	....
6, 000	. 000500	. 000000	. 000500	. 000000	....	....
7, 000	. 000500	. 000000	. 000500	. 000000	....	....
8, 000	. 000500	. 000000	. 000500	. 000000	....	....
9, 000	. 000500	. 000000	. 000500	. 000000	....	....
10, 000	. 000500	. 000000	. 000500	. 000000	....	....
11, 000	. 000500	. 000000	. 000500	. 000000	....	....
12, 000	. 000500	. 000000	. 000500	. 000000	....	....
13, 000	. 000500	. 000000	. 000500	. 000000	....	....
14, 000	. 000500	. 000000	. 000500	. 000000	....	....
15, 000	. 000500	. 000000	. 000500	. 000000	....	....
16, 000	. 001000	. 000500	. 001000	. 000500	....	....
17, 000	. 001000	. 000000	. 001000	. 000000	....	....
18. 000	. 001000	. 000000	. 001000	. 000000	....	....
19, 000	. 001000	. 000000	. 001000	. 000000	....	....
20, 000	. 001000	. 000000	. 001000	. 000000	....	....
21, 000	. 001000	. 000000	. 001000	. 000000	....	....
22, 000	. 001000	. 000000	. 001000	. 000000	....	....
23, 000	. 001000	. 000000	. 001000	. 000000	....	....
24, 000	. 001000	. 000000	. 001000	. 000000	....	....
25. 000	. 001500	. 000500	. 001500	. 000500	....	....
26, 000	. 001500	. 000000	. 001500	. 000000	....	....
27, 000	. 001500	. 000000	. 001500	. 000000	....	....
28, 000	. 001500	. 000000	. 001500	. 000000	....	....
29, 000	. 001500	. 000000	. 001500	. 000000	....	....
30, 000	. 001500	. 000000	. 001500	. 000000	....	....
31, 000	. 001500	. 000000	. 001500	. 000000	....	....
32, 000	. 001500	. 000000	. 001500	. 000000	....	....
33, 000	. 001500	. 000000	. 001500	. 000000	....	....
34, 000	. 001500	. 000000	. 001500	. 000000	....	....
35, 000	. 001500	. 000000	. 001500	. 000000	....	....
36, 000	. 001500	. 000000	. 001500	. 000000	....	....
37, 000	. 002000	. 000500	. 002000	. 000500	....	....
38, 000	. 002000	. 000000	. 002000	. 000000	....	....
39, 000	. 002000	. 000000	. 002000	. 000000	....	....
40, 000	. 002000	. 000000	. 002000	. 000000	....	....
41, 000	. 002000	. 000000	. 002000	. 000000	....	....
42, 000	. 002000	. 000000	. 002000	. 000000	....	....
43, 000	. 002000	. 000000	. 002000	. 000000	....	....
44, 000	. 002000	. 000000	. 002000	. 000000	....	....
45, 000	. 002000	. 000000	. 002000	. 000000	....	....
46, 000	. 002000	. 000000	. 002000	. 000000	....	....
47, 000	. 002000	. 000000	. 002000	. 000000	....	....
48, 000	. 002500	. 000500	. 002500	. 000500	....	....
49, 000	. 002500	. 000000	. 002500	. 000000	....	....
50, 000	. 003000	. 000500	. 002500	. 000000	. 000500	. 000500
51, 000	. 003500	. 000500	. 002000	— . 000500	. 001500	. 001000
52, 000	. 004000	. 000500	. 002000	. 000000	. 002000	. 000500
53, 000	. 004000	. 000000	. 001500	— . 000500	. 002500	. 000500
54, 000	004500	. 000500	. 002000	. 000500	. 002500	. 000000
55, 000	. 005000	. 000500	. 002000	. 000000	. 003000	. 000500
56, 000	. 006500	. 001500	. 002500	. 000500	. 004000	. 001000
57, 000	. 006500	. 000000	. 002500	. 000000	. 004000	. 000000
58, 000	. 007000	. 000500	. 001500	— . 001000	. 005500	. 001500
59, 000	. 008000	. 001000	. 002000	. 000500	. 006000	. 000500
60, 000	. 008500	. 000500	. 002500	. 000500	. 006000	. 000000
61, 000	. 009000	. 000500	. 002000	— . 000500	. 007000	. 001000
62, 000	. 010500	. 001500	. 002500	. 000500	. 008000	. 001000
63, 000	. 011000	. 000500	. 002500	. 000000	. 008500	. 000500
64, 000	. 013500	. 002500	. 003000	. 000500	. 010500	. 002000
65, 000	. 014000	. 000500	. 003000	. 000000	. 011000	. 000500
66. 000	. 014000	. 000000	. 002500	— . 000500	. 011500	. 000500
67, 000	. 015000	. 001000	. 002500	. 000000	. 012500	. 001000
68, 000	. 015500	. 000500	. 002500	. 000000	. 013000	. 000500
69, 000	. 016500	. 001000	. 002500	. 000000	. 014000	. 001000
70, 000	. 017500	. 001000	. 002500	. 000000	. 015000	. 001000
71, 000	. 018500	. 001000	. 003000	. 000500	. 015500	. 000500
72, 000	. 019000	. 000500	. 003000	. 000000	. 016000	. 000500
73, 000	. 020000	. 001000	. 002500	— . 000500	. 017500	. 001500
74, 000	. 021500	. 001500	. 003000	. 000500	. 018500	. 001000
75, 000	. 022500	. 001000	. 003000	. 000000	. 019500	. 001000
76, 000	. 023500	. 001000	. 003500	. 000500	. 020000	. 000500

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
77, 000	. 025500	. 002000	. 003500	. 000000	. 022000	. 002000
78, 000	. 026500	. 001000	. 003000	— . 000500	. 023500	. 001500
79, 000	. 028000	. 001500	. 003000	. 000000	. 025000	. 001500
80, 000	. 030000	. 002000	. 003000	. 000000	. 027000	. 002000
81, 000	. 032000	. 002000	. 004000	. 001000	. 028000	. 001000
82, 000	. 033500	. 001500	. 004000	. 000000	. 029500	. 001500
83, 000	. 035500	. 002000	. 004000	. 000000	. 031500	. 002000
84, 000	. 037500	. 002000	. 004000	. 000000	. 033500	. 002000
85, 000	. 039000	. 001500	. 004000	. 000000	. 035000	. 001500
86, 000	. 040500	. 001500	. 003500	. 000500	. 037000	. 002000
87, 000	. 043500	. 003000	. 003000	— . 000500	. 040500	. 003500
88, 000	. 047000	. 003500	. 004000	. 001000	. 043000	. 002500
89, 000	. 049500	. 002500	. 004000	. 000000	. 045500	. 002500
90, 000	. 053000	. 003500	. 004000	. 000000	. 049000	. 003500
91, 000	. 056500	. 003500	. 003500	— . 000500	. 053000	. 004000
92, 000	. 067500	. 011000	. 003500	. 000000	. 064000	. 011000
93, 000	. 071500	. 004000	. 004000	. 000500	. 067500	. 003500
94, 000	. 077500	. 006000	. 004500	. 000500	. 073000	. 005500
95, 000	. 086000	. 008500	. 005000	. 000500	. 081000	. 008000
96, 000	. 099500	. 013500	. 006000	. 001000	. 093500	. 012500
97, 000	. 130000	. 030500	. 007500	. 001500	. 122500	. 029000
98, 000	. 232500	. 102500	....	....	....	....

GENERAL SUMMARY.

Specific gravity		......
Tensile strength per square inch	pounds	98, 000
Elastic limit	do	49, 000
Extension per inch at rupture	inch	0. 232
Hardness		......
Reduction in diameter at point of rupture	inch	0. 130
Original area of cross-section	square inch	0. 2507
Area after rupture	inch	0. 1486
Position of rupture		center.
Character of surface		crystalline, dark gray large spot in center.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 2 inches long and 0. 565 inch in diameter, taken from rolled hoop, oil-tempered and annealed.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1, 000	0. 000000	0. 000000	0. 000000	0. 000000	....	....
2, 000	. 000000	. 000000	. 000000	. 000000	....	....
3, 000	. 000000	. 000000	. 000000	. 000000	....	....
4, 000	. 000000	. 000000	. 000000	. 000000	....	....
5, 000	. 000000	. 000000	. 000000	. 000000	....	....
6, 000	. 000000	. 000000	. 000000	. 000000	....	....
7, 000	. 000000	. 000000	. 000000	. 000000	....	....
8, 000	. 000000	. 000000	. 000000	. 000000	....	....
9, 000	. 000000	. 000000	. 000000	. 000000	....	....
10, 000	. 000000	. 000000	. 000000	. 000000	....	....
11, 000	. 000000	. 000000	. 000000	. 000000	....	....
12, 000	. 000000	. 000000	. 000000	. 000000	....	....
13, 000	. 000000	. 000000	. 000000	. 000000	....	....
14, 000	. 000250	. 000250	+ . 000250	. 000250	....	....
15, 000	. 000250	. 000000	. 000000	. 000000	....	....
16, 000	. 000250	. 000000	. 000000	. 000000	....	....
17, 000	. 000250	. 000000	+ . 000000	. 000000	....	....
18, 000	. 000250	. 000000	. 000000	. 000000	....	....
19, 000	. 000250	. 000000	. 000000	. 000000	....	....
20, 000	. 000250	. 000000	. 000000	. 000000	....	....
21, 000	. 000250	. 000000	. 000000	. 000000	....	....
22, 000	. 000250	. 000000	. 000000	. 000000	....	....
23, 000	. 000250	. 000000	. 000000	. 000000	....	....
24, 000	. 000250	. 000000	. 000000	. 000000	....	....
25, 000	. 000250	. 000000	. 000000	. 000000	....	....
26, 000	. 000250	. 000000	. 000250	. 000000	....	....

Table showing the extension, restoration, and permanent set, &c.—**Continued.**

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
27, 000	.000250	.000000	.000250	.000000	....	....
28, 000	.000250	.000000	.000250	.000000	....	....
29, 000	.000250	.000000	.000250	.000000	....	....
30, 000	.000250	.000000	.000250	.000000	....	....
31, 000	.000250	.000000	.000250	.000000	....	....
32, 000	.000250	.000000	.000250	.000000	....	....
33, 000	.000750	.000500	.000750	.000500	....	....
34, 000	.000750	.000000	.000750	.000000	....	....
35, 000	.000750	.000000	.000750	.000000	....	....
36, 000	.000750	.000000	.000750	.000000	....	....
37, 000	.000750	.000000	.000750	.000000	....	....
38, 000	.000750	.000000	.000750	.000000	....	....
39, 000	.000750	.000000	.000750	.000000	....	....
40, 000	.000750	.000000	.000750	.000000	....	....
41, 000	.000750	.000000	.000750	.000000	....	....
42, 000	.000750	.000000	.000750	.000000	....	....
43, 000	.000750	.000000	.000750	.000000	....	....
44, 000	.000750	.000000	.000750	.000000	....	....
45, 000	.000750	.000000	.000750	.000000	....	....
46, 000	.000750	.000000	.000750	.000000	....	....
47, 000	.000750	.000000	.000750	.000000	....	....
48, 000	.001250	.000500	.001250	.000000	....	....
49, 000	.002250	.001000	.002000	.000750	.000250	.000250
50, 000	.002750	.000500	.002000	.000000	.000750	.000500
51, 000	.003250	.000500	.001500	— .000500	.001750	.001000
52, 000	.003750	.000500	.001500	.000000	.002250	.000500
53, 000	.005250	.000500	.002000	.000500	.003250	.001000
54, 000	.006250	.001000	.002000	.000000	.004250	.001000
55, 000	.006750	.000500	.001500	— .000500	.005250	.001000
56, 000	.007750	.001000	.002000	.000500	.005750	.000500
57, 000	.008250	.000500	.002000	.000000	.006250	.000500
58, 000	.008750	.000500	.002000	.000000	.006750	.000500
59, 000	.009750	.001000	.002000	.000000	.007250	.000500
60, 000	.010750	.001000	.002000	.000000	.008250	.001000
61, 000	.011750	.001000	.002000	.000000	.009750	.001500
62, 000	.013250	.001500	.002000	.000000	.011250	.001500
63, 000	.014250	.001000	.002500	.000500	.011750	.000500
64, 000	.015250	.001000	.003000	.000500	.012750	.001000
65, 000	.015750	.000500	.002000	— .001000	.013250	.000500
66, 000	.017250	.001500	.003000	.001000	.014250	.001000
67, 000	.018250	.001000	.003000	.000000	.015250	.001000
68, 000	.019750	.001500	.002000	— .001000	.017250	.002000
69, 000	.021250	.001500	.002500	.000500	.018750	.001500
70, 000	.022750	.001500	.002500	.000000	.020250	.001500
71, 000	.023750	.001000	.002500	.000000	.021250	.001000
72, 000	.025750	.002000	.002500	.000000	.023250	.002000
73, 000	.027250	.001500	.003000	.000500	.024250	.001000
74, 000	.028750	.001500	.003000	.000000	.025750	.001500
75, 000	.031250	.002500	.003000	.000000	.028250	.002500
76, 000	.033250	.002000	.003000	.000000	.030250	.002000
77, 000	.034750	.001500	.003500	.000500	.031250	.001000
78, 000	.036750	.002000	.003000	— .000500	.033750	.002500
79, 000	.040750	.004000	.003500	.000500	.037250	.003500
80, 000	.043250	.002500	.003500	.000000	.039750	.002500
81, 000	.046250	.003000	.003500	.000000	.042750	.003000
82, 000	.050750	.004500	.003500	.000000	.047250	.004500
83, 000	.053750	.003000	.003500	.000000	.050250	.003000
84, 000	.061250	.007500	.004000	.000500	.057250	.007000
85, 000	.063250	.002000	.003000	— .001000	.060250	.003000
86, 000	.073750	.010500	.004000	.001000	.069750	.009500
87, 000	.078750	.005000	.004000	.000000	.074750	.005000
88, 000	.080250	.001500	.004500	.000500	.075750	.001000
89, 000	.083750	.003500	.004500	.000000	.079250	.003500
90, 000	.247250	.163500	....	....	....	....

GENERAL SUMMARY.

Specific gravity	
Tensile strength per square inch ......pounds..	90, 000
Elastic limit ......do...	48, 000
Extension per inch at rupture ......inch..	0. 2475
Hardiness	
Reduction in diameter at point of rupture ......inch..	0. 171
Original area of cross-section ......square inch..	0. 2507
Area after rupture ......do......	0. 1219
Position of rupture	one-third distance from shoulder.
Character of surface	fine, fibrous.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 8 inches long and 0.565 inch in diameter, taken from rolled hoop, oil-tempered and annealed.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000						
* * *						
7,000						
8,000						
9,000						
10,000						
11,000						
12,000						
13,000						
14,000						
15,000						
16,000						
17,000						
18,000						
19,000						
20,000						
21,000						
22,000						
23,000						
24,000						
25,000						
26,000						
27,000						
28,000						
29,000						
30,000						
31,000						
32,000						
33,000						
34,000						
35,000						
36,000						
37,000						
38,000						
39,000						
40,000						
41,000						
42,000						
43,000	.001375	.001375	.001375	.001875		
44,000	.001375	.000000	.001375	.000000		
45,000	.001500	.000125	.001500	.000125		
46,000	.001500	.000000	.001500	.000000		
47,000	.001500	.000000	.001500	.000000		
48,000	.001625	.000125	.001500	.000000	.000125	.000125
49,000	.001750	.000125	.001500	.000000	.000250	.000125
50,000	.001750	.000000	.001500	.000000	.000250	.000000
51,000	.001875	.000125	.001500	.000000	.000375	.000125
52,000	.002125	.000250	.001625	.000125	.000500	.000125
53,000	.002250	.000125	.001625	.000000	.000625	.000125
54,000	.002500	.000250	.001750	.000125	.000750	.000125
55,000	.002750	.000250	.001875	.000125	.000875	.000125
56,000	.003500	.000750	.002000	.000125	.001500	.000625
57,000	.004125	.000625	.002125	.000125	.002000	.000500
58,000	.004750	.000625	.002000	.000125	.002750	.000750
59,000	.005625	.000875	.002000	.000000	.003625	.000875
60,000	.006625	.001000	.002125	.000125	.004500	.000875
61,000	.007875	.001250	.002250	.000125	.005625	.001125
62,000	.008875	.001000	.002375	.000125	.006500	.000875
63,000	.009500	.000625	.002375	.000000	.007125	.000625
64,000	.010125	.000625	.002500	.000125	.007625	.000500
65,000	.011750	.001625	.002500	.000000	.009250	.001635
66,000	.012875	.001125	.002625	.000125	.010250	.001000
67,000	.013500	.000625	.002625	.000000	.010875	.000625
68,000	.015125	.001625	.002625	.000000	.012500	.001625
69,000	.016000	.000875	.002750	.000125	.013250	.000750
70,000	.016750	.000750	.002375	—.000375	.014375	.001125
71,000	.017750	.001000	.002250	—.000125	.015500	.001125
72,000	.019250	.001500	.002875	.000625	.016375	.000875
73,000	.020125	.000875	.002875	.000000	.017250	.000875
74 000	.022750	.002625	.003000	.000125	.019750	.002500
75 000	.024125	.001375	.003000	.000000	.021125	.001375
76 000	.024875	.000750	.003125	.000125	.021750	.000625
77,000	.026375	.001500	.003125	.000000	.023250	.001500
78,000	.028625	.002250	.003250	.000125	.025375	.002125

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
79, 000	. 031125	. 002500	. 003250	. 000000	. 027875	. 002500
80, 000	. 033125	. 002000	. 003500	. 000250	. 029625	. 001750
81, 000	. 034625	. 001500	. 003250	—. 000250	. 031875	. 001750
82, 000	. 038500	. 003875	. 003500	. 000250	. 035000	. 003625
83, 000	. 039875	. 001375	. 003625	. 000125	. 036250	. 001250
84, 000	. 044750	. 004875	. 003625	. 000000	. 041125	. 004875
85, 000	. 045375	. 000625	. 003500	—. 000125	. 041875	. 000750
86, 000	. 050750	. 005375	. 003750	. 000250	. 047000	. 005125
87, 000	. 051750	. 001000	. 003625	. 000125	. 048125	. 001125
88, 000	. 053500	. 001750	. 003750	. 000125	. 049750	. 001625
89, 000	. 061250	. 007750	. 004000	. 000250	. 057250	. 007500
* * *						
91, 200	. 121250	....	....	....	....	....

GENERAL SUMMARY.

Specific gravity	
Tensile strength per square inch .... pounds..	91, 200
Elastic limit .... do....	47, 000
Extension per inch at rupture .... inch..	0. 121
Hardness	
Reduction in diameter at point of rupture .... inch..	0. 165
Original area of cross-section .... square inches..	0. 25072
Area after rupture .... do....	0. 12566
Position of rupture	½ distance from shoulder
Character of surface	fine uniform fibrous

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 2 inches long and 0.566 inch in diameter, taken from rolled hoop, oil-tempered and annealed.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1, 000	0. 000000	0. 000000	0. 000000	0. 000000		
2, 000	. 000000	. 000000	. 000000	. 000000	....	....
3, 000	. 000000	. 000000	. 000000	. 000000	....	....
4, 000	. 000000	. 000000	. 000000	. 000000	....	....
5, 000	. 000000	. 000000	. 000000	. 000000	....	....
6, 000	. 000000	. 000000	. 000000	. 000000	....	....
7, 000	. 000000	. 000000	. 000000	. 000000	....	....
8, 000	. 000000	. 000000	. 000000	. 000000	....	....
9, 000	. 000000	. 000000	. 000000	. 000000	....	....
10, 000	. 000000	. 000000	. 000000	. 000000	....	....
11, 000	. 000000	. 000000	. 000000	. 000000	....	....
12, 000	. 000000	. 000000	. 000000	. 000000	....	....
13, 000	. 000000	. 000000	. 000000	. 000000	....	....
14, 000	. 000000	. 000000	. 000000	. 000000	....	....
15, 000	. 000000	. 000000	. 000000	. 000000	....	....
16, 000	. 000000	. 000000	. 000000	. 000000	....	....
17, 000	. 000000	. 000000	. 000000	. 000000	....	....
18, 000	. 000000	. 000000	. 000000	. 000000	....	....
19, 000	. 000000	. 000000	. 000000	. 000000	....	....
20, 000	. 000000	. 000000	. 000000	. 000000	....	....
21, 000	. 000000	. 000000	. 000000	. 000000	....	....
22, 000	. 000000	. 000000	. 000000	. 000000	....	....
23, 000	. 000000	. 000000	. 000000	. 000000	....	....
24, 000	. 000000	. 000000	. 000000	. 000000	....	....
25, 000	. 000000	. 000000	. 000000	. 000000	....	....
26, 000	. 000500	. 000500	. 000500	. 000500	....	....
27, 000	. 000500	. 000000	. 000500	. 000000	....	....
28, 000	. 000500	. 000000	. 000500	. 000000	....	....
29, 000	. 000500	. 000000	. 000500	. 000000	....	....
30, 000	. 000500	. 000000	. 000500	. 000000	....	....
31, 000	. 000500	. 000000	. 000500	. 000000	....	....
32, 000	. 000500	. 000000	. 000500	. 000000	....	....
33, 000	. 000500	. 000000	. 000500	. 000000	....	....
34, 000	. 000500	. 000000	. 000500	. 000000	....	....
35, 000	. 000500	. 000000	. 000500	. 000000	....	....
36, 000	. 001000	. 000500	. 001000	. 000500	....	....
37, 000	. 001000	. 000000	. 001000	. 000000	....	....

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
38, 000	.001000	.000000	.001000	.000000		
39, 000	.001000	.000000	.001000	.000000		
40, 000	.001000	.000000	.001000	.000000		
41, 000	.001000	.000000	.001000	.000000		
42, 000	.001000	.000000	.001000	.000000		
43, 000	.001000	.000000	.001000	.000000		
44, 000	.001000	.000000	.001000	.000000		
45, 000	.001000	000000	.001000	.000000		
46, 000	.001000	.000000	.001000	.000000		
47, 000	.001000	.000000	.001000	.000000		
48, 000	.001500	.000500	.001500	.000500		
49, 000	.001500	.000000	.001500	.000000		
50, 000	.001500	.000000	.001500	.000000		
51, 000	.001500	.000000	.001500	.000000		
52, 000	.001500	.000000	.001500	.000000		
53, 000	.001500	.000000	.001500	.000000		
54, 000	.002000	.000500	.001500	.000000	.000500	.000500
55, 000	.002000	.000000	.001500	.000000	.000500	.000000
56, 000	.002500	.000500	.001500	.000000	.001000	.000500
57, 000	.003000	.000300	.002000	.000500	.001000	.000000
58, 000	.003000	.000000	.001000	—.001000	.002000	.000100
59, 000	.005000	.002000	.002500	.001500	.002500	.000500
60, 000	.005500	.000500	.002500	.000000	.003000	.000500
61, 000	.005500	.000000	.002000	—.000500	.003500	.000500
62, 000	.007000	.001500	.002000	.000000	.005000	.001500
63, 000	.007500	.000500	.002000	.000000	.005500	.000500
64, 000	.008000	.000500	.002500	.000500	.005300	.000000
65, 000	.008500	.000500	.002000	—.000500	.006500	.001000
66, 000	.009000	.000500	.002000	.000000	.007000	.000500
67, 000	.010000	.001000	.002500	.000300	.007500	.000500
68, 000	.010500	.000500	.002000	—.000500	.008500	.001000
69, 000	.011500	.001000	.002500	.000500	.009000	.000500
70, 000	.012000	.000500	.002500	.000000	.009500	.000500
71, 000	.013000	.001000	.002500	.000000	.010500	.001000
72, 000	.014000	.001000	.002500	.000000	.011500	.001000
73, 000	.015000	.001000	.002500	.000000	.012500	.001000
74, 000	.016000	.001000	.002500	.000000	.013500	.001000
75, 000	.016500	.000500	.002500	.000000	.014000	.000500
76, 000	.018000	.001500	.002500	.000000	.015500	.001500
77, 000	.019500	.001500	.003000	.000500	.016500	.001000
78, 000	.020000	.000500	.003000	.000000	.017000	.000500
79, 000	.022000	.002000	.003500	.000500	.018500	.001500
80, 000	.023000	.001000	.003500	.000000	.019500	.001000
81, 000	.024500	.001500	.003500	.000000	.021000	.001500
82, 000	.025500	.001000	.003000	—.000500	.022500	.001500
83, 000	.027000	.001500	.003000	.000000	.024000	.001500
84, 000	.028000	.001000	.003000	.000000	.025000	.001000
85, 000	.029500	.001500	.003000	.000000	.026500	.001500
86, 000	.030500	.001000	.003000	.000000	.027500	.001000
87, 000	.033500	.003000	.003500	.000500	.030000	.002500
88, 000	.035500	.002000	.003500	.000000	.032000	.002000
89, 000	.038500	.003000	.003500	.000000	.035000	.003000
90, 000	.041000	.002500	.003500	.000000	.037500	.002500
91, 000	.043500	.002500	.004000	.000300	.039500	.002000
92, 000	.045500	.002000	.004000	.000000	.041500	.002000
93, 000	.052000	.006500	.004000	.000000	.048000	.006500
94, 000	.056000	.004000	.004500	.000500	.051500	.003500
95, 000	.057500	.001500	.004000	—.000500	.053500	.002000
96, 000	.064000	.006500	.004000	.000000	.060000	.006500
97, 000	.068500	.004500	.004500	.000500	.064000	.004000
98, 000	.081000	.012500	.004000	—.000500	.077000	.013000
99, 000	.095000	.014000	.005000	.001000	.090000	.012000
100, 000	.110000	.024000	.004500	—.000300	.114500	.024500
101, 000	.192000	.073000				

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds..	101, 000
Elastic limit	do..	53, 000
Extension per inch at rupture	inch..	0. 1925
Hardness		
Reduction in diameter at point of rupture	inch..	0. 1005
Original area of cross-section	square inch..	0. 2516
Area after rupture	square inch..	0. 1702
Position of rupture		½ distance from shoulder.
Character of surface		crystalline, with spot on one side of dull gray, rather loose structure.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 8 *inches long and* 0.567 *inch in diameter, taken from rolled hoop, oil-tempered and annealed.*

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000	0.000000	0.000000	0.000000	0.000000	....	....
* * * * *						
10,000	.000125	.000125	.000125	.000125	....	....
11,000	.000125	.000000	.000125	.000000	....	....
12,000	.000125	.000000	.000125	.000000	....	....
13,000	.000125	.000000	.000125	.000000	....	....
14,000	.000250	.000125	.000250	.000125	....	....
15,000	.000250	.000000	.000250	.000000	....	....
16,000	.000250	.000000	.000250	.000000	....	....
17,000	.000375	.000125	.000375	.000125	....	....
18,000	.000375	.000000	.000375	.000000	....	....
19,000	.000375	.000000	.000375	.000000	....	....
20,000	.000375	.000000	.000375	.000000	....	....
21,000	.000375	.000000	.000375	.000000	....	....
22,000	.000500	.000125	.000500	.000125	....	....
23,000	.000500	.000000	.000500	.000000	....	....
24,000	.000500	.000000	.000500	.000000	....	....
25,000	.000500	.000000	.000500	.000000	....	....
26,000	.000500	.000000	.000500	.000000	....	....
27,000	.000625	.000125	.000625	.000125	....	....
28,000	.000625	.000000	.000625	.000000	....	....
29,000	.000625	.000000	.000625	.000000	....	....
30,000	.000625	.000000	.000625	.000000	....	....
31,000	.000625	.000000	.000625	.000000	....	....
32,000	.000625	.000000	.000625	.000000	....	....
33,000	.000750	.000125	.000750	.000125	....	....
34,000	.000750	.000000	.000750	.000000	....	....
35,000	.000750	.000000	.000750	.000000	....	....
36,000	.000875	000125	.000875	.000125	....	....
37,000	.001000	.000000	.001000	.000000	....	....
38,000	.001000	.000000	.001000	.000000	....	....
39,000	.001000	.000000	.001000	.000000	....	....
40,000	001125	.000125	.001125	.000125	....	....
41,000	.001125	.000000	.001125	.000000	....	....
42,000	.001125	.000000	.001125	.000000	....	....
43,000	.001125	.000000	.001125	.000000	....	....
44,000	.001250	.000125	.001250	.000125	....	....
45,000	.001250	.000000	.001250	.000000	....	....
46,000	.001250	.000000	.001250	.000000	....	....
47,000	.001375	.000125	.001375	.000125	....	....
48,000	.001375	.000000	.001375	.000000	....	....
49,000	.001375	.000000	.001375	.000000	....	....
50,000	.001375	.000000	.001375	.000000	....	....
51,000	.001375	.000000	.001375	.000000	....	....
52,000	.001500	.000125	.001500	.000125	....	....
53,000	.001625	.000125	.001625	.000125	....	....
54,000	.001625	.000000	.001625	.000000	....	....
55,000	.001625	.000000	.001625	.000000	....	....
56,000	.001625	.000000	.001625	.000000	....	....
57,000	.001750	.000125	.001750	.000125	....	....
58,000	.001875	.000000	.001750	.000000	.000125	.000125
59,000	.001875	.000000	.001750	.000000	.000125	.000000
60,000	.002000	.000125	.001875	.000125	.000125	.000000
61,000	.002000	.000000	.001875	.000000	.000125	.000000
62,000	.002125	.000125	.001875	.000000	.000250	.000125
63,000	.002250	.000125	.001625	—.000125	.000625	.000375
64,000	.002375	.000125	.001625	.000000	.000750	.000125
65,000	.002625	.000250	.001625	.000000	.001000	.000250
66,000	.003250	.000525	.001750	.000125	.001500	.000500
67,000	.003875	.000625	.001875	.000125	.002000	.000500
68,000	.004750	.000875	.001750	—.000125	.003000	.001000
69,000	.005500	.000750	.001875	.000125	.003625	.000625
70,000	.006875	.001375	.002125	.000250	.004750	.001125
71,000	.007375	.000500	.002125	.000000	.005250	.000500
72,000	.008625	.001250	.002125	.000000	.006500	.001250
73,000	.009625	.001000	.002125	.000000	.007500	.001000
74,000	.011375	.000750	.002250	.000125	.008125	.000625
75,000	.011250	.000875	.002250	.000000	.009000	.000875
76,000	.012250	.001000	.002375	.000125	.009875	.000875
77,000	.013125	.000875	.002250	—.000125	.010875	.001000
78,000	.014125	.001000	.002625	.000375	.011500	.000625
79,000	.015125	.001000	.002500	—.000125	.012625	.001125
80,000	.016000	.000875	.002625	.000125	.013375	.000750
81,000	.017000	.001000	.002625	.000000	.014375	.001000
82,000	.017750	.000750	.002625	.000000	.015125	.000750
83,000	.020125	.002375	.002875	.000250	.017250	.002125

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
84, 000	. 021000	. 000875	. 002750	—. 000125	. 018250	. 001000
85, 000	. 021750	. 000750	. 002875	. 000125	. 018875	. 000625
86, 000	. 023000	. 001250	. 003000	. 000125	. 020000	. 001125
87, 000	. 024625	. 001625	. 003125	. 000125	. 021500	. 001500
88, 000	. 025875	. 001250	. 003125	. 000000	. 022750	. 001250
89, 000	. 027500	. 001625	. 003500	. 000375	. 024000	. 001250
90, 000	. 028625	. 001125	. 003500	. 000000	. 025125	. 001250
91, 000	. 031875	. 003250	. 003625	. 000125	. 028250	. 003125
92, 000	. 032500	. 000625	. 003625	. 000000	. 028875	. 000625
93, 000	. 033500	. 001000	. 003625	. 000000	. 029875	. 001000
94, 000	. 037125	. 003625	. 004000	. 000275	. 033125	. 003250
95, 000	. 039000	. 001875	. 003875	—. 000125	. 035125	. 002000
96, 000	. 044375	. 005375	. 004750	. 000875	. 039625	. 004500
97, 000	. 045750	. 001375	. 004000	—. 000750	. 041750	. 002125
98, 000	. 048875	. 003125	. 004000	. 000000	. 044875	. 003125
99, 000	. 052250	. 003375	. 004125	. 000125	. 048125	. 003250
100, 000	. 059125	. 006865	. 004375	. 000250	. 054750	. 006625
103, 500	. 111875	. 052750				

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds..	103, 500
Elastic limit	do....	57, 000
Extension per inch at rupture	inch..	0. 11188
Hardness		
Reduction in diameter at point of rupture	inch..	0. 107
Original area of cross-section	square inch..	0. 2525
Area after rupture	do....	0. 1662
Position of rupture		at middle point
Character of surface		fine crystalline, with small dull gray core

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Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 3 *inches long and* 0.560 *inch in diameter, taken from rolled and annealed hoop.*

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1, 000	0. 000000	0. 000000	0. 000000			
* * * * *						
22, 000	. 000000	. 000000	. 000000			
23, 000	. 000333	. 000333	. 000333	. 000333		
24, 000	. 000333	. 000000	. 000333	. 000000		
25, 000	. 000333	. 000000	. 000333	. 000000		
26, 000	. 000333	. 000000	. 000333	. 000000		
27, 000	. 000333	. 000000	. 000333	. 000000		
28, 000	. 000333	. 000000	. 000333	. 000000		
29, 000	. 003333	. 000000	. 000333	. 000000		
30, 000	. 000333	. 000000	. 000333	. 000000		
31, 000	. 000333	. 000000	. 000333	. 000000		
32. 000	. 000333	. 000000	. 000333	. 000000		
33, 000	. 000333	. 000000	. 000333	. 000000		
34, 000	. 000333	. 000000	. 000333	. 000000		
35, 000	. 000333	. 000000	. 000333	. 000000		
36, 000	. 000666	. 000333	. 000666	. 000333		
37, 000	. 000666	. 000000	. 000666	. 000000		
38, 000	. 000666	. 000000	. 000666	. 000000		
39, 000	. 000666	. 000000	. 000666	. 000000		
40, 000	. 000666	. 000000	. 000666	. 000000		
41, 000	. 000666	. 000000	. 000666	. 000000		
42, 000	. 000666	. 000000	. 000666	. 000000		
43, 000	. 000666	. 000000	. 000666	. 000000		
44, 000	. 000666	. 000000	. 000666	. 000000		
45, 000	. 001000	. 000334	. 001000	. 000334		

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
46, 000	0. 001000	0. 000000	0. 001000	0. 000000	....	....
47, 000	.001333	.000333	.001833	.000333	....	....
48, 000	.001666	.000333	.001666	.000333	....	....
49, 000	.002000	.000334	.001666	.000000	.000333	.000333
50, 000	.003000	.001000	.002000	.000334	.001000	.000667
51, 000	.003333	.000333	.002000	.000000	.001333	.000333
52, 000	.003666	.000333	.002000	.000000	.001666	.000333
53, 000	.004000	.000334	.002000	.000000	.002000	.000334
54, 000	.005000	.001000	.002333	.000333	.002666	.000666
55, 000	.005333	.000333	.002000	.000333	.003333	.000667
56, 000	.005666	.000333	.002000	.000000	.003666	.000333
57, 000	.006333	.000667	.002333	.000333	.004000	.000334
58, 000	.007000	.000667	.002666	.000333	.004333	.000333
59, 000	.007333	.000333	.002666	.000000	.004666	.000333
60, 000	.008000	.000667	.002666	.000000	.005333	.000667
61, 000	.008666	.000666	.002666	.000000	.006000	.000667
62, 000	.009333	.000667	.002666	.000000	.006666	.000666
63, 000	.009666	.000333	.002666	.000000	.007000	.000334
64, 000	.010333	.000667	.002666	.000000	.007666	.000666
65, 000	.011000	.000667	.002666	.000000	.008333	.000667
66, 000	.011666	.000666	.002666	.000000	.009000	.000667
67, 000	.012333	.000667	.003000	.000334	.009333	.000333
68, 000	.013000	.000667	.003000	.000000	.010000	.000667
69, 000	.014000	.001000	.003000	.000000	.011000	.001000
70, 000	.015000	.001000	.003000	.000000	.012000	.001000
71, 000	.016000	.001000	.003333	.000333	.012666	.000666
72, 000	.017000	.001000	.003666	.000333	.013333	.000667
73, 000	.017666	.000666	.003333	—.000333	.014333	.001000
74, 000	.018666	.001000	.003333	.000000	.015333	.001000
75, 000	.019333	.000667	.003333	.000000	.016000	.000667
76, 000	.020000	.000667	.003000	—.000333	.017000	.001000
77, 000	.021333	.001333	.003333	.000333	.018000	.001000
78, 000	.022333	.001000	.003333	.000000	.019000	.001000
79, 000	.023333	.001000	.003333	.000000	.020000	.001000
80, 000	.024666	.001333	.003666	.000333	.021000	.001000
81, 000	.025666	.001000	.004000	.000334	.021666	.000666
82, 000	.027333	.001667	.004000	.000000	.023333	.001667
83, 000	.029000	.001667	.004000	.000000	.025000	.001667
84, 000	.030333	.001333	.004000	.000000	.026333	.001333
85, 000	.032000	.001667	.004000	.000000	.028000	.001667
86, 000	.033333	.001333	.004333	.000333	.029000	.001000
87, 000	.035666	.002333	.004333	.000000	.031333	.002333
88, 000	.037000	.001334	.004000	.000333	.033000	.001667
89, 000	.039666	.002666	.004333	.000333	.035333	.002333
90, 000	.042333	.002667	.004333	.000000	.038000	.002667
91, 000	.044000	.001667	.004666	.000333	.039333	.001333
92, 000	.046333	.001333	.004000	—.000666	.042333	.003000
93, 000	.049666	.003333	.004000	.000000	.045666	.003333
94, 000	.053000	.003334	.004333	.000333	.048666	.003000
95, 000	.056333	.003333	.004333	.000000	.052000	.003334
96, 000	.058666	.002333	.004333	.000000	.054333	.002333
97, 000	.065000	.006334	.004666	.000333	.060333	.006000
98, 000	.068000	.003000	.004616	.000000	.063333	.003000
99, 000	.074333	.006333	.004000	—.000666	.070333	.007000
100, 000	.081333	.007000	.004666	.000666	.076666	.006333
101, 000	.093000	.011667	.004333	—.000333	.088666	.012000
102, 000	.101666	.008666	.004333	.000000	.097333	.008667
103, 000	.124000	.022334	.005000	.000667	.119000	.021667
104, 000	.189000	.065000	....	....	....	....

GENERAL SUMMARY.

Specific gravity	
Tensile strength per square inch .... pounds..	104, 000
Elastic limit .... do ...	48, 000
Extension per inch at rupture .... inch..	0. 189
Hardness	
Reduction in diameter at point of rupture .... inch..	0. 069
Original area of cross-section .... square inch..	0. 2463
Area after rupture .... do....	0. 1893
Position of rupture ⅓ distance from shoulder	
Character of surface, excepting one small spot, of uniform crystalline structure	

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 3 inches long and 0.561 inch in diameter, taken from rolled and annealed hoop.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000	0.000000	0.000000	0.000000	0.000000	....	....
* * * * *						
17,000	.000000	.000000	.000000	.000000	....	....
18,000	.000000	.000000	.000000	.000000	....	....
19,000	.000000	.000000	.000000	.000000	....	....
20,000	.000000	.000000	.000000	.000000	....	....
21,000	.000000	.000000	.000000	.000000	....	....
22,000	.000000	.000000	.000000	.000000	....	....
23,000	.000000	.000000	.000000	.000000	....	....
24,000	.000000	.000000	.000000	.000000	....	....
25,000	.000000	.000000	.000000	.000000	....	....
26,000	.000000	.000000	.000000	.000000	....	....
27,000	.000000	.000000	.000000	.000000	....	....
28,000	.000333	.000333	.000333	.000333	....	....
29,000	.000333	.000000	.000333	.000000	....	....
30,000	.000333	.000000	.000333	.000000	....	....
31,000	.000333	.000000	.000333	.000000	....	....
32,000	.000333	.000000	.000333	.000000	....	....
33,000	.000333	.000000	.000333	.000000	....	....
34,000	.000333	.000000	.000333	.000000	....	....
35,000	.000333	.000000	.000333	.000000	....	....
36,000	.000333	.000000	.000333	.000000	....	....
37,000	.000333	.000000	.000333	.000000	....	....
38,000	.000333	.000000	.000333	.000000	....	....
39,000	.000333	.000000	.000333	.000000	....	....
40,000	.000333	.000000	.000333	.000000	....	....
41,000	.000666	.000333	.000666	.000333	....	....
42,000	.000666	.000000	.000666	.000000	....	....
43,000	.000666	.000000	.000666	.000000	....	....
44,000	.000666	.000000	.000666	.000000	....	....
45,000	.000666	.000000	.000666	.000000	....	....
46,000	.000666	.000000	.000666	.000000	....	....
47,000	.000666	.000000	.000666	.000000	....	....
48,000	.001000	.000334	.000666	.000000	....	....
49,000	.001666	.000666	.001666	.001000	....	....
50,000	.002000	.000334	.001666	.000000	.000333	.000333
51,000	.002333	.000333	.001666	.000000	.000666	.000333
52,000	.003000	.000667	.001666	.000000	.001333	.000667
53,000	.003666	.000666	.002000	.000334	.001666	.000333
54,000	.004000	.000334	.002333	.000333	.001666	.000000
55,000	.004333	.000333	.002333	.000000	.002000	.000334
56,000	.005333	.001000	.002333	.000000	.003000	.001000
57,000	.005666	.000333	.002333	.000000	.003333	.000333
58,000	.006666	.001000	.002333	.000000	.004333	.001000
59,000	.007333	.000667	.002333	.000000	.005000	.000667
60,000	.007666	.000333	.002333	.000000	.005333	.000333
61,000	.008333	.000667	.002666	.000333	.005666	.000333
62,000	.009000	.000667	.002666	.000000	.006333	.000667
63,000	.009666	.000666	.002666	.000000	.007000	.000667
64,000	.010000	.000334	.002666	.000000	.007333	.000333
65,000	.010666	.000666	.002666	.000000	.008000	.000667
66,000	.011666	.001000	.003000	.000334	.008666	.000666
67,000	.012333	.000667	.003000	.000000	.009333	.000667
68,000	.013000	.000667	.003000	.000000	.010000	.000667
69,000	.014000	.001000	.003333	.000333	.010666	.000666
70,000	.015000	.001000	.003333	.000000	.011666	.001000
71,000	.016000	.001000	.003333	.000000	.012666	.001000
72,000	.016666	.000666	.003333	.000000	.013333	.000667
73,000	.017333	.000667	.003333	.000000	.014000	.000667
74,000	.018333	.001000	.003333	.000000	.015000	.001000
75,000	.019000	.000667	.003333	.000000	.015666	.000666
76,000	.020333	.001333	.003666	.000333	.016666	.001000
77,000	.021333	.001000	.003666	.000000	.017666	.001000
78,000	.022333	.001000	.003666	.000000	.018666	.001000
79,000	.023666	.001333	.003333	.000333	.020333	.001667
80,000	.025000	.001334	.003333	.000000	.021666	.001333
81,000	.026000	.001000	.003333	.000000	.022666	.001000
82,000	.028333	.002333	.003666	.000333	.024666	.002000
83,000	.030000	.001667	.004333	.000667	.025666	.001000
84,000	.031333	.001333	.003666	−.000667	.027666	.002000
85,000	.033666	.002333	.003666	.000000	.030000	.002334
86,000	.035000	.001334	.004000	+.000334	.031000	.001000
87,000	.038000	.003000	.004333	.000333	.033666	.002666
88,000	.039666	.001666	.003333	−.001000	.036333	.002667
89,000	.042000	.002334	.003666	.000333	.038333	.002000
90,000	.045000	.003000	.004333	.000667	.040666	.002333

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
91,000	.048666	.003666	.004333	.000000	.044333	.003667
92,000	.052000	.003334	.004666	.000333	.047333	.003000
93,000	.055666	.003666	.004333	—.000333	.051333	.004000
94,000	.061000	.005334	.004666	.000333	.056333	.005000
95,000	.065666	.004666	.004000	—.000666	.061666	.005333
96,000	.070666	.005000	.005333	.001333	.065333	.003667
97,000	.077000	.006334	.004666	—.000667	.072333	.007000
98,000	.087000	.010000	.005000	.000334	.082000	.009667
99,000	.097000	.010000	.004666	—.000334	.092333	.010333
100,000	.111000	.014000	.005333	.000667	.105666	.013333
101,000	.179666	.068666	....	....	....	....

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds	101,000
Elastic limit	do	48,000
Extension per inch at rupture	inch	0.180
Hardness		
Reduction in diameter at point of rupture	inch	0.085
Original area of cross-section	sq. inch	0.2472
Area after rupture	do	0.1780
Position of rupture		½ distance from shoulder.
Character of surface		crystalline, with small, dull-gray spot on one side.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 3 *inches long and* 0.561 *inch in diameter, taken from rolled and annealed hoop.*

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000	0.000000	0.000000	0.000000	0.000000	....	....
2,000	.000000	.000000	.000000	.000000	....	....
3,000	.000000	.000000	.000000	.000000	....	....
4,000	.000000	.000000	.000000	.000000	....	....
5,000	.000000	.000000	.000000	.000000	....	....
6,000	.000000	.000000	.000000	.000000	....	....
7,000	.000000	.000000	.000000	.000000	....	....
8,000	.000000	.000000	.000000	.000000	....	....
9,000	.000000	.000000	.000000	.000000	....	....
10,000	.000000	.000000	.000000	.000000	....	....
11,000	.000000	.000000	.000000	.000000	....	....
12,000	.000000	.000000	.000000	.000000	....	....
13,000	.000333	.000333	.000333	.000333	....	....
14,000	.000333	.000000	.000333	.000000	....	....
15,000	.000333	.000000	.000333	.000000	....	....
16,000	.000333	.000000	.000333	.000000	....	....
17,000	.000333	.000000	.000333	.000000	....	....
18,000	.000333	.000000	.000333	.000000	....	....
19,000	.000333	.000000	.000333	.000000	....	....
20,000	.000333	.000000	.000333	.000000	....	....
21,000	.000333	.000000	.000333	.000000	....	....
22,000	.000333	.000000	.000333	.000000	....	....
23,000	.000333	.000000	.000333	.000000	....	....
24,000	.000666	.000333	.000666	.000333	....	....
25,000	.000666	.000000	.000666	.000000	....	....
26,000	.000666	.000000	.000666	.000000	....	....
27,000	.000666	.000000	.000666	.000000	....	....
28,000	.000666	.000000	.000666	.000000	....	....
29,000	.000666	.000000	.000666	.000000	....	....
30,000	.000666	.000000	.000666	.000000	....	....
31,000	.000666	.000000	.000666	.000000	....	....
32,000	.000666	.000000	.000666	.000000	....	....
33,000	.000666	.000000	.000666	.000000	....	....
34,000	.000666	.000000	.000666	.000000	....	....
35,000	.000666	.000000	.000666	.000000	....	....
36,000	.000666	.000000	.000666	.000000	....	....
37,000	.000666	.000000	.000666	.000000	....	....
38,000	.000666	.000000	.000666	.000000	....	....

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
39,000	.001000	.000334	.001000	.000334	....	....
40,000	.001000	.000000	.001000	.000000	....	....
41,000	.001000	.000000	.001000	.000000	....	....
42,000	.001000	.000000	.001000	.000000	....	....
43,000	.001000	.000000	.001000	.000000	....	....
44,000	.001333	.000333	.001333	.000333	.000000	.000000
45,000	.001333	.000000	.001333	.000000	.000000	.000000
46,000	.001333	.000000	.001333	.000000	.000000	.000000
47,000	.001666	.000333	.001666	.000333	.000000	.000000
48,000	.001666	.000000	.001333	.000333	.000333	.000333
49,000	.002000	.000334	.001333	.000000	.000666	.000333
50,000	.002666	.000666	.001666	.000333	.001000	.000334
51,000	.003333	.000667	.001666	.000000	.001666	.000666
52,000	.004000	.000667	.002000	.000334	.002000	.000334
53,000	.004666	.000666	.002333	.000333	.002333	.000333
54,000	.005000	.000334	.002333	.000000	.002666	.000333
55,000	.005333	.000333	.002333	.000000	.003000	.000334
56,000	.006333	.001000	.002000	—.000333	.004333	.001333
57,000	.006666	.000333	.002000	.000000	.004666	.000333
58,000	.007000	.000334	.002000	.000000	.005000	.000334
59,000	.007666	.000666	.002333	.000333	.005333	.000333
60,000	.008333	.000667	.002333	.000000	.006000	.000667
61,000	.009000	.000667	.002333	.000000	.006666	.000666
62,000	.009333	.000333	.002333	.000000	.007000	.000334
63,000	.010666	.001333	.003000	.000667	.007666	.000666
64,000	.011000	.000334	.002333	.000333	.008666	.001000
65,000	.011666	.000666	.001666	—.000667	.009000	.000334
66,000	.012333	.000667	.002666	.001000	.009666	.000666
67,000	.013000	.000667	.003000	.000334	.010000	.000334
68,000	.013666	.000666	.003000	.000000	.010666	.000666
69,000	.014666	.001000	.003000	.000000	.011666	.001000
70,000	.015333	.000667	.003000	.000000	.012333	.000667
71,000	.016000	.000667	.002666	—.000334	.013333	.001000
72,000	.016666	.000666	.003000	.000334	.013666	.000333
73,000	.017333	.000667	.003000	.000000	.014333	.000667
74,000	.018333	.001000	.003000	.000000	.015333	.001000
75,000	.019333	.001000	.003000	.000000	.016333	.001000
76,000	.020333	.001000	.003333	.000333	.017000	.000667
77,000	.022000	.000667	.003333	.000000	.018666	.001666
78,000	.022333	.000333	.003000	—.000333	.019333	.000667
79,000	.024000	.001667	.003333	.000333	.020666	.001333
80,000	.024666	.000666	.003000	—.000333	.021666	.001000
81,000	.025666	.001000	.003000	.000000	.022666	.001000
82,000	.027000	.000334	.003666	.000666	.023333	.000667
83,000	.029000	.002000	.004000	.000334	.025000	.001667
84,000	.031000	.002000	.003666	—.000334	.027333	.002333
85,000	.032333	.001333	.003333	—.000333	.029000	.001667
86,000	.033666	.001333	.003333	.000000	.030333	.001333
87,000	.035333	.001667	.004000	.000667	.031333	.001000
88,000	.037666	.002333	.004000	.000000	.033666	.002333
89,000	.039000	.001334	.003666	—.000334	.035333	.001667
90,000	.040666	.001666	.004000	.000334	.036666	.001333
91,000	.044000	.003334	.004000	.000000	.040000	.003334
92,000	.046000	.005000	.004000	.000000	.042000	.002000
93,000	.050333	.004333	.004000	.000000	.046333	.004333
94,000	.053000	.002667	.004333	.000333	.048666	.002333
95,000	.056666	.003666	.004666	.000333	.052000	.003334
96,000	.060000	.003334	.004333	—.000333	.055666	.003666
97,000	.063666	.003666	.004666	.000333	.059000	.003334
98,000	.068333	.004667	.005000	.000334	.063333	.004333
99,000	.074000	.005667	.006333	.001333	.067666	.004333
100,000	.081333	.007333	.005000	—.001333	.076333	.008667
101,000	.088666	.007333	.004666	—.000334	.084000	.007667
102,000	.098666	.010000	.005000	.000334	.093666	.009666
103,000	.119333	.020667	.003666	—.001334	.115666	.022000
104,000	.195000	.075667	....	....	....	....

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds	104,000
Elastic limit	do	47,000
Extension per inch at rupture	inch	0.195
Hardness		
Reduction in diameter at point of rupture	inch	0.081
Original area of cross-section	sq. inch	0.2472
Area after rupture	do	0.1810
Position of rupture		⅓ distance from shoulder.
Character of surface		uniform crystalline, with small, dull spot on one side.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 2 inches long and 0.565 inch in diameter, taken from rolled and annealed hoop.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000	0.000000	0.000000	0.000000	0.000000	....	....
2,000	.000000	.000000	.000000	.000000	....	....
3,000	.000000	.000000	.000000	.000000	....	....
4,000	.000000	.000000	.000000	.000000	....	....
5,000	.000000	.000000	.000000	.000000	....	....
6,000	.000000	.000000	.000000	.000000	....	....
7,000	.000000	.000000	.000000	.000000	....	....
8,000	.000000	.000000	.000000	.000000	....	....
9,000	.000000	.000000	.000000	.000000	....	....
10,000	.000000	.000000	.000000	.000000	....	....
11,000	.000000	.000000	.000000	.000000	....	....
12,000	.000500	.000500	.000500	.000500	....	....
13,000	.000500	.000000	.000500	.000000	....	....
14,000	.000500	.000000	.000500	.000000	....	....
15,000	.000500	.000000	.000500	.000000	....	....
16,000	.000500	.000000	.000500	.000000	....	....
17,000	.000500	.000000	.000500	.000000	....	....
18,000	.000500	.000000	.000500	.000000	....	....
19,000	.000500	.000000	.000500	.000000	....	....
20,000	.000500	.000000	.000500	.000000	....	....
21,000	.000500	.000000	.000500	.000000	....	....
22,000	.000500	.000000	.000500	.000000	....	....
23,000	.000500	.000000	.000500	.000000	....	....
24,000	.000500	.000000	.000500	.000000	....	....
25,000	.000500	.000000	.000500	.000000	....	....
26,000	.001000	.000500	.001000	.000500	....	....
27,000	.001000	.000000	.001000	.000000	....	....
28,000	.001000	.000000	.001000	.000000	....	....
29,000	.001000	.000000	.001000	.000000	....	....
30,000	.001000	.000000	.001000	.000000	....	....
31,000	.001000	.000000	.001000	.000000	....	....
32,000	.001000	.000000	.001000	.000000	....	....
33,000	.001000	.000000	.001000	.000000	....	....
34,000	.001000	.000000	.001000	.000000	....	....
35,000	.001000	.000000	.001000	.000000	....	....
36,000	.001000	.000000	.001000	.000000	....	....
37,000	.001000	.000000	.001000	.000000	....	....
38,000	.001500	.000500	.001500	.000500	....	....
39,000	.001500	.000000	.001500	.000000	....	....
40,000	.002000	.000500	.002000	.000500	....	....
41,000	.002000	.000000	.001500	.000500	.000500	.000500
42,000	.002500	.000500	.001500	.000000	.001000	.000500
43,000	.002500	.000000	.001500	.000000	.001000	.000000
44,000	.003000	.000500	.001500	.000000	.001500	.000500
45,000	.003500	.000500	.001500	.000000	.002000	.000500
46,000	.004000	.000500	.001500	.000000	.002500	.000500
47,000	.004500	.000500	.001500	.000000	.003000	.000500
48,000	.005000	.000500	.002000	.000500	.003000	.000000
49,000	.005500	.000500	.002000	.000000	.003500	.000500
50,000	.006000	.000500	.002000	.000000	.004000	.000500
51,000	.006500	.000500	.002000	.000000	.004500	.000500
52,000	.007000	.000500	.002000	.000000	.005000	.000500
53,000	.007500	.000500	.002000	.000000	.005500	.000500
54,000	.008000	.000500	.002500	.000500	.005500	.000000
55,000	.008500	.000500	.002500	.000000	.006000	.000500
56,000	.009000	.000500	.002500	.000000	.006500	.000500
57,000	.009500	.000500	.002500	.000000	.007000	.000500
58,000	.010000	.000500	.002000	—.000500	.008000	.001000
59,000	.010500	.000500	.002000	.000000	.008500	.000500
60,000	.011000	.000500	.002000	.000000	.009000	.000500
61,000	.011500	.000500	.002000	.000000	.009500	.000500
62,000	.012500	.001000	.002500	.000500	.010000	.000500
63,000	.013000	.000500	.002500	.000000	.010500	.000500
64,000	.014000	.001000	.003000	.000500	.011000	.000500
65,000	.014500	.000500	.003000	.000000	.011500	.000500
66,000	.015500	.001000	.003000	.000000	.012500	.001000
67,000	.016500	.001000	.003000	.000000	.013500	.001000
68,000	.017000	.000500	.003500	.000500	.013500	.000000
69,000	.017500	.000500	.003000	—.000500	.014500	.001000
70,000	.018500	.001000	.003000	.000000	.015500	.001000
71,000	.019500	.001000	.003000	.000000	.016500	.001000
72,000	.020500	.001000	.003500	.000500	.017000	.000500
73,000	.021000	.000500	.003500	.000000	.017500	.000500
74,000	.022000	.001000	.003500	.000000	.018500	.001000
75,000	.022500	.000500	.003500	.000000	.019000	.000500
76,000	.023500	.001000	.003000	—.000500	.020500	.001500
77,000	.024500	.001000	.003500	.000500	.021000	.000500

Table showing extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
78, 000	.025500	.001000	.003500	.000000	.022000	.001000
79, 000	.027000	.001500	.003000	—.000500	.023000	.001000
80, 000	.028500	.001500	.004000	.001000	.024500	.001500
81, 000	.030000	.001500	.004000	.000000	.026000	.001500
82, 000	.031500	.001500	.004500	.000500	.027000	.001000
83, 000	.032500	.001000	.004500	.000000	.028000	.001000
84, 000	.034000	.001500	.004500	.000000	.029500	.001500
85, 000	.035500	.001500	.004500	.000000	.031000	.001500
86, 000	.037000	.001500	.004500	.000000	.032500	.001500
87, 000	.038000	.001000	.004000	—.000500	.034000	.001500
88, 000	.040000	.002000	.003500	—.000500	.036500	.002500
89, 000	.043500	.003500	.004500	.001000	.039000	.002500
90, 000	.046000	.002500	.004500	.000000	.041500	.002500
91, 000	.048500	.002500	.004500	.000000	.044000	.002500
92, 000	.050500	.002000	.004500	.000000	.046000	.002000
93, 000	.053500	.003000	.004500	.000000	.049000	.003000
94, 000	.057000	.003500	.004500	.000000	.052500	.003500
95, 000	.060500	.003500	.005000	.000500	.055500	.003000
96, 000	.064000	.003500	.005000	.000000	.059000	.003500
97, 000	.068500	.004500	.005000	.000000	.063500	.004500
98, 000	.074000	.006500	.005000	.000000	.069000	.005500
99, 000	.083000	.009000	.006000	.001000	.077000	.008000
100, 000	.089000	.006000	.006000	.000000	.083000	.006000
101, 000	.098000	.009000	.005500	.000500	.092500	.009500
102, 000	.115500	.017500	.005500	.000000	.110000	.017500

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds..	103, 000
Elastic limit	do....	40, 000
Extension per inch at rupture	inch..	0. 164
Hardness		
Reduction in diameter at point of rupture		0. 062
Original area of cross-section	square inch..	0. 2507
Area after rupture	do....	0. 1987
Position of rupture		near middle of specimen.
Character of surface		rather coarse crystalline, with dull-gray spot on one side.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 8 *inches long and* 0.565 *inch in diameter, taken from rolled and annealed hoop.*

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1, 000	0. 000000	0. 000000	0. 000000	0. 000000	....	....
2, 000	.000000	.000000	.000000	.000000	....	....
3, 000	.000000	.000000	.000000	.000000	....	....
4, 000	.000125	.000125	.000125	.000125	....	....
5, 000	.000125	.000000	.000125	.000000	....	....
6, 000	.000125	.000000	.000125	.000000	....	....
7. 000	.000125	.000000	.000125	.000000	....	....
8, 000	.000250	.000125	.000250	.000125	....	....
9, 000	.000250	.000000	.000250	.000000	....	....
10, 000	.000250	.000000	.000250	.000000	....	....
11, 000	.000250	.000000	.000250	.000000	....	....
12. 000	.000250	.000000	.000250	.000000	....	....
13, 000	.000250	.000000	.000250	.000000	....	....
14, 000	.000375	.000125	.000375	.000125	....	....
15, 000	.000375	.000000	.000375	.000000	....	....
16, 000	.000375	.000000	.000375	.000000	....	....
17, 000	.000375	.000000	.000375	.000000	....	....
18, 000	.000375	.000000	.000375	.000000	....	....
19, 000	.000500	.000125	.000500	.000125	....	....
20, 000	.000500	.000000	.000500	.000000	....	....
21, 000	.000500	.000000	.000500	.000000	....	....
22, 000	.000500	.000000	.000500	.000000	....	....
23, 000	.000625	.000125	.000625	.000125	....	....
24, 000	.000625	.000000	.000625	.000000	....	....
25, 000	.000625	.000000	.000625	.000000	....	....
26, 000	.000625	.000000	.000625	.000000	....	....
27, 000	.000750	.000125	.000750	.000125	....	....

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
28, 000	.000750	.000000	.000750	.000000	....	....
29, 000	.000750	.000000	.000750	.000000	....	....
30, 000	.000875	.000125	.000875	.000125	....	....
31, 000	.000875	.000000	.000875	.000000	....	....
32, 000	.000875	.000000	.000875	.000000	....	....
33, 000	.001000	.000125	.001000	.000125	....	....
34, 000	.001000	.000000	.001000	.000000	....	....
35, 000	.001000	.000000	.001000	.000000	....	....
36, 000	.001125	.000125	.001125	.000125	....	....
37, 000	.001125	.000000	.001125	.000000	....	....
38, 000	.001125	.000000	.001125	.000000	....	....
39, 000	.001250	.000125	.001250	.000125	....	....
40, 000	.001250	.000000	.001250	.000000	....	....
41, 000	.001375	.000125	.001375	.000125	....	....
42, 000	.001375	.000000	.001375	.000000	....	....
43, 000	.001500	.000125	.001500	.000125	....	....
44, 000	.001500	.000000	.001500	.000000	....	....
45, 000	.001625	.000125	.001500	.000000	.000125	.000125
46, 000	.001750	.000125	.001500	.000000	.000250	.000125
47, 000	.001875	.000125	.001625	.000125	.000250	.000000
48, 000	.002125	.000250	.001625	.000000	.000500	.000250
49, 000	.003000	.000875	.001750	.000125	.001250	.000750
50, 000	.003625	.000625	.001625	—.000125	.002000	.000750
51, 000	.004250	.000625	.001750	.000125	.002400	.000400
52, 000	.004500	.000250	.001750	.000000	.002750	.000350
53, 000	.005375	.000875	.001875	.000125	.003500	.000750
54, 000	.006000	.000625	.002000	.000125	.004000	.000500
55, 000	.007000	.001000	.002125	.000125	.004875	.000875
56, 000	.007250	.000250	.002125	.000000	.005125	.000250
57, 000	.008750	.001500	.002250	.000125	.006500	.001375
58, 000	.009125	.000375	.002375	.000125	.006750	.000250
59, 000	.009750	.000625	.002375	.000000	.007375	.000625
60, 000	.009875	.000125	.002375	.000000	.007500	.000125
61, 000	.010125	.000250	.002375	.000000	.007750	.000250
62, 000	.010750	.000625	.002500	.000125	.008250	.000500
63, 000	.011375	.000625	.002500	.000000	.008875	.000625
64, 000	.012000	.000625	.002500	.000000	.009500	.000625
65, 000	.012875	.000875	.002625	.000125	.010250	.000250
66, 000	.013375	.000570	.002625	.000000	.010750	.000500
67, 000	.014875	.001500	.002750	.000125	.012125	.001375
68, 000	.015375	.000500	.002750	.000000	.012625	.000500
69, 000	.015875	.000500	.002750	.000000	.013125	.000500
70, 000	.016750	.000875	.002875	.000125	.013875	.000750
71, 000	.017500	.000750	.002750	—.000125	.014750	.000875
72, 000	.018500	.001000	.003000	.000250	.015500	.000750
73, 000	.019125	.000625	.003000	.000000	.016125	.000625
74, 000	.020375	.001250	.003000	.000000	.017375	.001250
75, 000	.021125	.000750	.003000	.000000	.018125	.000750
76, 000	.022250	.001125	.003250	.003250	.019000	.000875
77, 000	.023500	.001250	.003125	—.000125	.020375	.001375
78, 000	.024500	.001000	.003250	.000125	.021350	.000875
79, 000	.026125	.001625	.003500	.000250	.022625	.001375
80, 000	.027250	.001125	.003375	—.000125	.023885	.001260
81, 000	.028875	.001625	.003500	.000125	.025375	.001490
82, 000	.030625	.001750	.003750	.000250	.026875	.001500
83, 000	.032000	.001375	.003750	.000000	.028250	.001295
84, 000	.033750	.001750	.003875	.000125	.029875	.001625
85, 000	.035250	.001500	.003750	—.000125	.031500	.001625
86, 000	.037250	.002000	.004000	.000250	.033250	.001750
87, 000	.039625*	.002375	.004000	.000000	.035625	.002375
88, 000	.041250	.001625	.003375	—.000125	.037875	.002250
89, 000	.044000	.002750	.004250	.000875	.039750	.001885
90, 000	.046625	.002625	.004125	—.000125	.042500	.002750
91, 000	.050375	.003750	.004375	.000250	.046000	.003500
92, 000	.053250	.002875	.004375	.000000	.048875	.002875
*93, 000	.057750	.004500	.004625	.000250	.053125	.004250
100, 000	0.150000	.092250	(†)	(†)	(†)	(†)

* Guage removed. † Specimen broke.

GENERAL SUMMARY.

Specific gravity..
Tensile strength per square inch ....pounds.. 100, 000
Elastic limit ....do.... 44, 000
Extension per inch at rupture ....inch.. 0. 15
Hardness ....
Reduction in diameter at point of rupture ....inch.. 0. 082
Original area of cross-section.....................................square inch.. 0. 2507
Area after rupture..do.... 0. 1832
position of rupture ....3¾ inches from lower shoulder.
haracter of surface..................crystalline, with dull-gray core extending on one place to outside.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 2 inches long and 0.566 inch in diameter, taken from rolled and annealed hoop.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000	0.000000	0.000000	0.000000	0.000000	....	....
* * *						
12,000	.000000	.000000	.000000	.000000	....	....
13,000	.000000	.000000	.000000	.000000	....	....
14,000	.000000	.000000	.000000	.000000	....	....
15,000	.000000	.000000	.000000	.000000	....	....
16,000	.000000	.000000	.000000	.000000	....	....
17,000	.000000	.000000	.000000	.000000	....	....
18,000	.000000	.000000	.000000	.000000	....	....
19,000	.000000	.000000	.000000	.000000	....	....
20,000	.000000	.000000	.000000	.000000	....	....
21,000	.000000	.000000	.000000	.000000	....	....
22,000	.000000	.000000	.000000	.000000	....	....
23,000	.000000	.000000	.000000	.000000	....	....
24,000	.000000	.000000	.000000	.000000	....	....
25,000	.000000	.000000	.000000	.000000	....	....
26,000	.000000	.000000	.000000	.000000	....	....
27,000	.000000	.000000	.000000	.000000	....	....
28,000	.000000	.000000	.000000	.000000	....	....
29,000	.000000	.000000	.000000	.000000	....	....
30,000	.000000	.000000	.000000	.000000	....	....
31,000	.000000	.000000	.000000	.000000	....	....
32,000	.000000	.000000	.000000	.000000	....	....
33,000	.000000	.000000	.000000	.000000	....	....
34,000	.000500	.000500	.000500	.000500	....	....
35,000	.000500	.000000	.000500	.000000	....	....
36,000	.000500	.000000	.000500	.000000	....	....
37,000	.000500	.000000	.000500	.000000	....	....
38,000	.000500	.000000	.000500	.000000	....	....
39,000	.001000	.000500	.001000	.000500	....	....
40,000	.001500	.000500	.001000	.000000	.000500	.000500
41,000	.002000	.000500	.001000	.000000	.001000	.000500
42,000	.003000	.001000	.001000	.000000	.002000	.001000
43,000	.004000	.001000	.001500	.000500	.002500	.000500
44,000	.004500	.000500	.001500	.000000	.003000	.000500
45,000	.005000	.000500	.001500	.000000	.003500	.000500
46,000	.005000	.000000	.001000	—.000500	.004000	.000500
47,000	.005500	.000500	.001500	.000500	.004000	.000000
48,000	.006000	.000500	.001500	.000000	.004500	.000500
49,000	.006500	.000500	.001500	.000000	.005000	.000500
50,000	.007000	.000500	.001500	.000000	.005500	.000500
51,000	.008000	.001000	.002000	.000500	.006000	.000500
52,000	.008500	.000500	.002000	.000000	.006500	.000500
53,000	.009000	.000500	.002000	.000000	.007000	.000500
54,000	.009500	.000500	.002000	.000000	.007500	.000500
55,000	.010000	.001000	.002000	.000000	.008000	.000500
56,000	.010500	.000500	.002000	.000000	.008500	.000500
57,000	.011000	.000500	.002000	.000000	.009000	.000500
58,000	.012000	.001000	.002000	.000000	.010000	.001000
59,000	.012500	.000500	.002500	.000500	.010000	.000000
60,000	.013000	.000500	.002500	.000000	.010500	.000500
61,000	.014000	.001000	.002000	—.000500	.012000	.001500
62,000	.015000	.001000	.002500	.000500	.012500	.000500
63,000	.016000	.001000	.002500	.000000	.013500	.001000
64,000	.016500	.000500	.002500	.000000	.014000	.000500
65,000	.017000	.000500	.002500	.000000	.014500	.000500
66,000	.018000	.001000	.002500	.000000	.015500	.001000
67,000	.018500	.000500	.002500	.000000	.016000	.000500
68,000	.019500	.001000	.002500	.000000	.017000	.001000
69,000	.020500	.001000	.003000	.000500	.017500	.000500
70,000	.021000	.000500	.003000	.000000	.018000	.000500
71,000	.022500	.001500	.003000	.000000	.019500	.001500
72,000	.023500	.001000	.003000	.000000	.020500	.001000
73,000	.024500	.001000	.003000	.000000	.021500	.001000
74,000	.025500	.001000	.003000	.000500	.022000	.000500
75,000	.027000	.001500	.004000	.000500	.023000	.001000
76,000	.028000	.001000	.003500	—.000500	.024500	.001500
77,000	.029000	.001000	.003500	.000000	.025500	.001000
78,000	.030000	.001000	.003500	.000000	.026500	.001000
79,000	.031500	.001500	.003500	.000000	.028000	.001500
80,000	.033000	.001500	.003500	.000000	.029500	.001500
81,000	.035000	.002000	.003500	.000000	.031500	.002000
82,000	.037500	.002500	.003500	.000000	.034000	.002500
83,000	.039000	.001500	.004000	.000500	.035000	.001000

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
84, 000	.040000	.001000	.003500	—.000500	.036500	.001500
85, 000	.042500	.002500	.004500	.001000	.038000	.001500
86, 000	.044000	.001500	.004000	—.000500	.040000	.002000
87, 000	.046000	.002000	.004000	.000000	.042000	.002000
88, 000	.048500	.002500	.004500	.000500	.044000	.002000
89, 000	.052000	.003500	.004500	.000000	.047500	.003500
90, 000	.055500	.003500	.005000	.000500	.050500	.003000
91, 000	.057000	.001500	.004000	—.001000	.053000	.002500
92, 000	.060000	.003000	.004500	.000500	.055500	.002500
* * *						
100, 000	.135000	.075000	....	....	....	....

GENERAL SUMMARY.

Specific gravity ....
Tensile strength per square inch..........................pounds.. 100, 000
Elastic limit ....do.... 39, 000
Extension per inch at rupture..inch.. 0. 135
Hardness ....
Reduction in diameter at point of rupture..................................inch.. 0. 050
Original area of cross-section ....square inch.. 0. 2516
Area after rupture ....do.... 0. 2091
Position of rupture ....near center.
Character of surface...............................rather coarse crystalline, with small dull core.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 2 inches long and 0.566 *inch in diameter, taken from rolled and annealed hoop.*

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1, 000	0. 000000	0. 000000	0. 000000	0. 000000	....	....
2, 000	.000000	.000000	.000000	.000000	....	....
3, 000	.000000	.000000	.000000	.000000	....	....
4, 000	.000000	.000000	.000000	.000000	....	....
5, 000	.000000	.000000	.000000	.000000	....	....
6, 000	.000000	.000000	.000000	.000000	....	....
7, 000	.000000	.000000	.000000	.000000	....	....
8, 000	.000000	.000000	.000000	.000000	....	....
9, 000	.000000	.000000	.000000	.000000	....	....
10, 000	.000000	.000000	.000000	.000000	....	....
11, 000	.000000	.000000	.000000	.000000	....	....
12, 000	.000000	.000000	.000000	.000000	....	....
13, 000	.000000	.000000	.000000	.000000	....	....
14, 000	.000000	.000000	.000000	.000000	....	....
15, 000	.000000	.000000	.000000	.000000	....	....
16, 000	.000000	.000000	.000000	.000000	....	....
17, 000	.000000	.000000	.000000	.000000	....	....
18, 000	.000000	.000000	.000000	.000000	....	....
19, 000	.000000	.000000	.000000	.000000	....	....
20, 000	.000000	.000000	.000000	.000000	....	....
21, 000	.000000	.000000	.000000	.000000	....	....
22, 000	.000500	.000500	.000500	.000500	....	....
23, 000	.000500	.000000	.000500	.000000	....	....
24, 000	.000500	.000000	.000500	.000000	....	....
25, 000	.000500	.000000	.000500	.000000	....	....
26, 000	.000500	.000000	.000500	.000000	....	....
27, 000	.000500	.000000	.000500	.000000	....	....
28, 000	.000500	.000000	.000500	.000000	....	....
29, 000	.000500	.000000	.000500	.000000	....	....
30, 000	.000500	.000000	.000500	.000000	....	....
31, 000	.001000	.000500	.001000	.000500	....	....
32, 000	.001000	.000000	.001000	.000000	....	....
33, 000	.001000	.000000	.001000	.000000	....	....
34, 000	.001000	.000000	.001000	.000000	....	....
35, 000	.001000	.000000	.001000	.000000	....	....
36, 000	.001000	.000000	.001000	.000000	....	....

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
37, 000	.001000	.000000	.001000	.000000	....	....
38, 000	.001000	.000000	.001000	.000000	....	....
39, 000	.001500	.000500	.001500	.000500	....	....
40, 000	.002000	.000500	.001500	.000000	.000500	....
41, 000	.002500	.000500	.001500	.000000	.001000	....
42, 000	.003000	.000500	.001500	.000000	.001500	....
43, 000	.003500	.000500	.001500	.000000	.002000	....
44, 000	.004500	.001000	.002000	.000500	.002500	.000500
45, 000	.004500	.000000	.002000	.000000	.002500	.000000
46, 000	.005090	.000500	.002000	.000000	.003000	.000500
47, 000	.005500	.000500	.002000	.000000	.003500	.000500
48, 000	.006000	.000500	.002000	.000000	.004000	.000500
49, 000	.006500	.000500	.001500	−.000500	.005000	.001000
50, 000	.007000	.000500	.002000	.000500	.005000	.000000
51, 000	.007500	.000500	.002000	.000000	.005500	.000500
52, 000	.008000	.000500	.002000	.000000	.006000	.000500
53, 000	.009000	.001000	.002000	.000000	.007000	.001000
54, 000	.009500	.000500	.002000	.000000	.007500	.000500
55, 000	.010000	.000500	.002000	.000000	.008000	.000500
56, 000	.010500	.000500	.002000	.000000	.008500	.000500
57, 000	.011500	.001000	.002500	.000500	.009000	.000500
58, 000	.012000	.000500	.002500	.000000	.009500	.000500
59, 000	.012500	.000500	.002500	.000000	.010000	.000500
60, 000	.013000	.000500	.002500	.000000	.010500	.000500
61, 000	.014000	.001000	.003000	.000500	.011000	.000500
62, 000	.014500	.000500	.002500	−.000500	.012000	.001000
63, 000	.015500	.001000	.003000	.000500	.012500	.000500
64, 000	.016500	.001000	.003000	.000000	.013500	.001000
65, 000	.017000	.000500	.003000	.000000	.014000	.000500
66, 000	.017500	.000500	.002500	−.000500	.015000	.001000
67, 000	.018500	.001000	.002500	.000000	.016000	.001000
68, 000	.019500	.001000	.003000	.000500	.016500	.000500
69, 000	.020500	.001000	.003000	.000000	.017500	.001000
70, 000	.021500	.001000	.003500	.000500	.018000	.000500
71, 000	.022000	.000500	.003500	.000000	.018500	.000500
72, 000	.023500	.001500	.003500	.000000	.020000	.001500
73, 000	.024500	.001000	.003500	.000000	.021000	.001000
74, 000	.026000	.001500	.004000	.000500	.022000	.001000
75, 000	.027000	.001000	.004000	.000000	.023000	.001000
76, 000	.028500	.001500	.004000	.000000	.024500	.001500
77, 000	.030000	.001500	.004000	.000000	.026000	.001500
78, 000	.032000	.002000	.005000	.001000	.027000	.001000
79, 000	.033000	.001000	.004500	+.000500	.028560	.001500
80, 000	.034500	.001500	.004000	−.000500	.030500	.002000
81, 000	.036000	.001500	.004000	.000000	.032000	.001500
82, 000	.037500	.001500	.004500	.000500	.033000	.001000
83, 000	.040000	.002500	.004000	−.000500	.036000	.003000
84, 000	.041500	.001500	.004000	.000000	.037500	.001500
85, 000	.043500	.002000	.004500	.000500	.039000	.001500
86, 000	.045000	.001500	.005000	.000500	.040500	.001500
87, 000	.049500	.004500	.005000	.000000	.044500	.004000
88, 000	.051000	.001500	.005000	.000000	.046000	.001500
89, 000	.052500	.001500	.005000	.000000	.047500	.001500
90, 000	.056000	.003500	.005500	.000500	.050500	.003000
91, 000	.061500	.005500	.005000	−.000500	.056500	.006000
92, 000	.065000	.003500	.005500	.000500	.059500	.003000
93, 000	.068000	.003000	.005500	.000000	.062500	.003000
94, 000	.073500	.005500	.005500	.000000	.068000	.005500
95, 000	.081000	.007500	.005500	.000000	.075500	.007500
96, 000	.089500	.008500	.006500	.001000	.083000	.007500
97, 000	.099500	.010000	.005500	−.001000	.094000	.011000
98, 000	.112000	.012500	.005500	.000000	.106500	.012500
99, 000	.158500	.046500	....	....	....	....
100, 000	....	....	....	....	....	....

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds..	99, 000
Elastic limit	do..	39, 000
Extension per inch at rupture	inch..	0. 1585
Hardness		
Reduction in diameter at point of rupture	inch..	0. 05
Original area of cross-section	square inch..	0. 2516
Area after rupture	do..	0. 2091
Position of rupture	one-third distance from shoulder.	
Character of surface	rather coarse crystalline structure, with small dull gray spot on one side.	

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 3 *inches long and* 0.567 *inch in diameter, taken from rolled and annealed hoop.*

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000	0.000000	0.000000	0.000000	0.000000	0.000000	....
2,000	.000000	.000000	.000000	.000000	.000000	....
3,000	.000000	.000000	.000000	.000000	.000000	....
4,000	.000000	.000000	.000000	.000000	....	....
5,000	.000000	.000000	.000000	.000000	....	....
6,000	.000000	.000000	.000000	.000000	....	....
7,000	.000000	.000000	.000000	.000000	....	....
8,000	.000000	.000000	.000000	.000000	....	....
9,000	.000000	.000000	.000000	.000000	....	....
10,000	.000000	.000000	.000000	.000000	....	....
11,000	.000000	.000000	.000000	.000000	....	....
12,000	.000000	.000000	.000000	.000000	....	....
13,000	.000000	.000000	.000000	.000000	....	....
14,000	.000000	.000000	.000000	.000000	....	....
15,000	.000000	.000000	.000000	.000000	....	....
16,000	.000000	.000000	.000000	.000000	....	....
17,000	.000000	.000000	.000000	.000000	....	....
18,000	.000000	.000000	.000000	.000000	....	....
19,000	.000000	.000000	.000000	.000000	....	....
20,000	.000000	.000000	.000000	.000000	....	....
21,000	.000000	.000000	.000000	.000000	....	....
22,000	.000000	.000000	.000000	.000000	....	....
23,000	.000000	.000000	.000000	.000000	....	....
24,000	.000333	.000333	.000333	.000333	....	....
25,000	.000333	.000000	.000333	.000000	....	....
26,000	.000333	.000000	.000333	.000000	....	....
27,000	.000333	.000000	.000333	.000000	....	....
28,000	.000333	.000000	.000333	.000000	....	....
29,000	.000333	.000000	.000333	.000000	....	....
30,000	.000333	.000000	.000333	.000000	....	....
31,000	.000333	.000000	.000333	.000000	....	....
32,000	.000333	.000000	.000333	.000000	....	....
33,000	.000333	.000000	.000333	.000000	....	....
34,000	.000333	.000000	.000333	.000000	....	....
35,000	.000333	.000000	.000333	.000000	....	....
36,000	.000333	.000000	.000333	.000000	....	....
37,000	.000333	.000000	.000333	.000000	....	....
38,000	.000333	.000000	.000333	.000000	....	....
39,000	.000666	.000333	.000666	.000333	....	....
40,000	.000666	.000000	.000666	.000000	....	....
41,000	.000666	.000000	.000666	.000000	....	....
42,000	.001000	.000334	.001000	.000334	....	....
43,000	.001333	.000333	.001000	.000000	.000333	.000333
44,000	.002000	.000667	.001000	.000000	.001000	.000667
45,000	.002333	.000333	.001333	.000333	.001000	.000000
46,000	.002333	.000000	.001000	— .000333	.001333	.000333
47,000	.003000	.000667	.001334	.000334	.001666	.000333
48,000	.003333	.000333	.001333	— .000001	.002000	.000334
49,000	.004000	.000667	.001334	.000001	.002666	.000666
50,000	.004333	.000333	.001333	— .000001	.003000	.000334
51,000	.005000	.000667	.001334	.000001	.003666	.000666
52,000	.005333	.000333	.001333	— .000001	.004000	.000334
53,000	.006000	.000667	.001667	.000334	.004333	.000333
54,000	.006333	.000333	.001333	— .000334	.005000	.000667
55,000	.007000	.000667	.001667	.000334	.005333	.000333
56,000	.007666	.000666	.001666	— .000001	.006000	.000667
57,000	.008000	.000334	.001667	.000001	.006333	.000333
58,000	.008666	.000666	.002000	.000333	.006666	.000333
59,000	.009000	.000334	.002000	.000000	.007000	.000334
60,000	.009666	.000666	.002000	.000000	.007666	.000666
61,000	.010333	.000667	.002000	.000000	.008333	.000667
62,000	.011000	.000667	.002000	.000000	.009000	.000667
63,000	.011666	.000666	.002333	.000333	.009333	.000333
64,000	.012000	.000334	.002334	.000001	.009666	.000333
65,000	.013000	.001000	.002334	.000000	.010666	.001000
66,000	.013666	.000666	.002333	— .000001	.011333	.000667
67,000	.014333	.000667	.002333	.000000	.012000	.000667
68,000	.015000	.000667	.002667	.000334	.012333	.000333
69,000	.015333	.000333	.002333	— .000334	.013000	.000667
70,000	.016333	.001000	.002667	.000334	.013666	.000666
71,000	.017333	.001000	.002667	.000000	.014666	.001000
72,000	.018333	.001000	.003000	.000333	.015333	.000667
73,000	.019000	.000667	.003000	.000000	.016000	.000667
74,000	.020000	.001000	.003000	.000000	.017000	.001000
75,000	.021000	.001000	.003000	.000000	.018000	.001000
76,000	.021666	.000666	.003000	.000000	.018666	.000666

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
77,000	.022666	.001000	.003000	.000000	.019666	.001000
78,000	.023666	.001000	.003000	.000000	.020666	.001000
79,000	.024666	.001000	.003000	.000000	.021666	.001000
80,000	.026333	.001667	.003333	.000334	.023000	.001334
81,000	.028000	.001667	.003667	.000334	.024333	.001333
82,000	.029333	.001000	.003667	.000000	.025666	.001333
83,000	.030333	.001000	.003333	— .000334	.027000	.001334
84,000	.032000	.001667	.003334	.000001	.028666	.001666
85,000	.033333	.001333	.004000	.000666	.029333	.000667
86,000	.035000	.001667	.004000	.000000	.031000	.001667
87,000	.037000	.002000	.004000	.000000	.033000	.002000
88,000	.038666	.001666	.004000	.000000	.034666	.001666
89,000	.041000	.002334	.004000	.000000	.037000	.002334
90,000	.043000	.002000	.004334	.000334	.038666	.001666
91,000	.045000	.002000	.004000	— .000334	.041000	.002334
92,000	.047333	.002333	.004333	.000333	.043000	.002000
93,000	.050333	.003000	.004333	.000000	.046000	.003000
94,000	.053333	.003000	.004333	.000000	.049000	.003000
95,000	.057000	.003667	.004667	.000334	.052333	.003000
96,000	.060666	.003666	.005000	.000333	.055666	.003333
97,000	.066666	.006000	.005333	.000333	.061333	.005667
98,000	.069666	.003000	.005000	— .000333	.064666	.003333
99,000	.074333	.004667	.004000	— .001000	.070333	.005667
100,000	.081000	.006667	.005000	.001000	.076000	.005667
101,000	.093000	.012000	.005334	.000334	.087666	.011666
102,000	.109333	.016333	.006333	.000999	.103000	.015834
103,000	.150333	.041000	....	....	....	....

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds	103,000
Elastic limit	do	42,000
Extension per inch at rupture	inch	0.150
Hardness		
Reduction in diameter at point of rupture	inch	0.055
Original area of cross-section	square inch	0.2525
Area after rupture	do	0.2059
Position of rupture		near middle.
Character of surface		compact crystalline, with small dull gray spot on one side

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 6 *inches long and* 0.561 *inch in diameter, taken from hammered hoop, oil-tempered and annealed.*

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000	0.000000	0.000000	0.000000	0.000000	....	....
* * * * *						
17,000	.000166	.000166	.000166	.000166	....	....
18,000	.000166	.000000	.000166	.000000	....	....
19,000	.000166	.000000	.000166	.000000	....	....
20,000	.000166	.000000	.000166	.000000	....	....
21,000	.000166	.000000	.000166	.000000	....	....
22,000	.000166	.000000	.000166	.000000	....	....
23,000	.000166	.000000	.000166	.000000	....	....
24,000	.000166	.000000	.000166	.000000	....	....
25,000	.000166	.000000	.000166	.000000	....	....
26,000	.000333	.000167	.000333	.000167	....	....
27,000	.000333	.000000	.000333	.000000	....	....
28,000	.000333	.000000	.000333	.000000	....	....
29,000	.000333	.000000	.000333	.000000	....	....
30,000	.000333	.000000	.000333	.000000	....	....
31,000	.000333	.000000	.000333	.000000	....	....
32,000	.000500	.000167	.000500	.000167	....	....
33,000	.000500	.000000	.000500	.000000	....	....
34,000	.000500	.000000	.000500	.000000	....	....
35,000	.000500	.000000	.000500	.000000	....	....
36,000	.000500	.000000	.000500	.000000	....	....

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
37,000	.000500	.000000	.000500	.000000		
38,000	.000500	.003000	.000500	.000000		
39,000	.000666	.000166	.000666	.000166		
40,000	.000666	.000000	.000666	.000000		
41,000	.000666	.000000	.000666	.000000		
42,000	.000666	.000000	.000666	.000000		
43,000	.000666	.000000	.000666	.000000		
44,000	.000833	.000167	.000833	.000167		
45,000	.000833	.000000	.000833	.000000		
46,000	.000833	.000000	.000833	.000000		
47,000	.000833	.000000	.000833	.000000		
48,000	.000833	.000000	.000833	.000000		
49,000	.000833	.000000	.000833	.000000		
50,000	.001000	.000167	.001000	.000167		
51,000	.001000	.000000	.001000	.000000		
52,000	.001000	.000000	.001000	.000000		
53,000	.001000	.000000	.001000	.000000		
54,000	.001166	.000166	.001166	.000166		
55,000	.001166	.000000	.001166	.000000		
56,000	.001166	.000000	.001166	.000000		
57,000	.001333	.000167	.001333	.000167		
58,000	.001333	.000000	.001333	.000000		
59,000	.001500	.000167	.001500	.000167		
60,000	.001500	.000000	.001500	.000000		
61,000	.001500	.000000	.001500	.000000		
62,000	.001833	.000333	.001833	.000333		
63,000	.002000	.000167	.001666	— .000167	.000166	.000166
64,000	.002500	.000500	.002333	.000667	.000166	.000000
65,000	.002833	.000333	.002333	.000000	.000500	.000334
66,000	.003666	.000833	.002500	.000167	.001166	.000666
67,000	.004500	.000834	.002500	.000000	.002000	.000834
68,000	.005666	.001166	.002666	.000166	.003000	.001000
69,000	.007666	.002000	.003000	.000334	.004666	.001666
70,000	.008166	.000500	.002833	— .000167	.005333	.000667
71,000	.008833	.000667	.002833	.000000	.006000	.000667
72,000	.009500	.000667	.002833	.000000	.006666	.000666
73,000	.010500	.001000	.003000	.000167	.007500	.000834
74,000	.012000	.001500	.003166	.000166	.008833	.001333
75,000	.013000	.001000	.003333	.000167	.009666	.000833
76,000	.014000	.001000	.003166	— .000167	.010833	.001167
77,000	.015000	.001000	.003333	.000167	.011666	.000833
78,000	.015833	.000833	.003333	.000000	.012500	.000834
79,000	.017166	.001333	.003500	.000167	.013666	.001166
80,000	.018000	.000834	.003500	.000000	.014500	.000834
81,000	.019833	.001833	.003666	.000166	.016166	.001666
82,000	.021166	.001833	.003833	.000167	.017333	.001167
83,000	.022500	.001333	.003666	— .000167	.018833	.001500
84,000	.024500	.002000	.003833	.000167	.020666	.001833
85,000	.025666	.001166	.003833	.000000	.021833	.001167
86,000	.027500	.001834	.003833	.000000	.023666	.001833
87,000	.029000	.001500	.004000	.000167	.025000	.001334
88,000	.030666	.001666	.004000	.000000	.026666	.001666
89,000	.031666	.001000	.004166	.000166	.027666	.001000
90,000	.036166	.004500	.004166	.000000	.032000	.004334
91,000	.037500	.001334	.004333	.000167	.033166	.001166
92,000	.039666	.002166	.004333	.000000	.035333	.002167
93,000	.044333	.004667	.004333	.000000	.040000	.004667
94,000	.047833	.003500	.004333	.000000	.043500	.003500
95,000	.051666	.003833	.004500	.000167	.047333	.003833
96,000	.058166	.006500	.004833	.000333	.053333	.006000
97,000	.061666	.003500	.004833	.000000	.057000	.003667
98,000	.069500	.007834	.004833	.000000	.064666	.607666
99,000	.071833	.002333	.004833	.000000	.067000	.002334
100,000	.092833	.021000	.005333	.000500	.087500	.020500
101,000	.142833	.050000				

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds..	101,000
Elastic limit	do...	62,000
Extension per inch at rupture	inch..	0.143
Hardness		
Reduction in diameter at point of rupture	inch..	0.127
Original area of cross-section	square inch..	0.2472
Area after rupture	do...	0.1479
Position of rupture		½ inch from shoulder.
Character of surface		fine crystalline structure, with large, dull, fibrous spot on one side.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 6 *inches long and* 0.562 *inch in diameter, taken from hammered hoop, oil-tempered and annealed.*

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000	0.000000	0.000000	0.000000	0.000000	....	....
* * * * *						
5,000	.000166	.000166	.000166	.000166	....	....
6,000	.000166	.000000	.000166	.000000	....	....
7,000	.000166	.000000	.000166	.000000	....	....
8,000	.000166	.000000	.000166	.000000	....	....
9,000	.000166	.000000	.000166	.000000	....	....
10,000	.000333	.000167	.000333	.000167	....	....
11,000	.000333	.000000	.000333	.000000	....	....
12,000	.000333	.000000	.000333	.000000	....	....
13,000	.000333	.000000	.000333	.000000	....	....
14,000	.000333	.000000	.000333	.000000	....	....
15,000	.000333	.000000	.000333	.000000	....	....
16,000	.000333	.000000	.000333	.000000	....	....
17,000	.000500	.000167	.000500	.000167	....	....
18,000	.000500	.000000	.000500	.000000	....	....
19,000	.000500	.000000	.000500	.000000	....	....
20,000	.000500	.000000	.000500	.000000	....	....
21,000	.000500	.000000	.000500	.000000	....	....
22,000	.000500	.000000	.000500	.000000	....	....
23,000	.000666	.000166	.000666	.000166	....	....
24,000	.000666	.000000	.000666	.000000	....	....
25,000	.000666	.000000	.000666	.000000	....	....
26,000	.000666	.000000	.000666	.000000	....	....
27,000	.000666	.000000	.000666	.000000	....	....
28,000	.000833	.000167	.000833	.000167	....	....
29,000	.000833	.000000	.000833	.000000	....	....
30,000	.000833	.000000	.000833	.000000	....	....
31,000	.000833	.000000	.000833	.000000	....	....
32,000	.001000	.000167	.001000	.000167	....	....
33,000	.001000	.000000	.001000	.000000	....	....
34,000	.001000	.000000	.001000	.000000	....	....
35,000	.001000	.000000	.001000	.000000	....	....
36,000	.001000	.000000	.001000	.000000	....	....
37,000	.001000	.000000	.001000	.000000	....	....
38,000	.001166	.000166	.001166	.000166	....	....
39,000	.001166	.000000	.001166	.000000	....	....
40,000	.001166	.000000	.001166	.000000	....	....
41,000	.001166	.000000	.001166	.000000	....	....
42,000	.001166	.000000	.001166	.000000	....	....
43,000	.001333	.000167	.001333	.000167	....	....
44,000	.001333	.000000	.001333	.000000	....	....
45,000	.001333	.000000	.001333	.000000	....	....
46,000	.001333	.000000	.001333	.000000	....	....
47,000	.001333	.000000	.001333	.000000	....	....
48,000	.001500	.000167	.001500	.000167	....	....
49,000	.001500	.000000	.001500	.000000	....	....
50,000	.001666	.000166	.001666	.000166	....	....
51,000	.001666	.000000	.001666	.000000	....	....
52,000	.001666	.000000	.001666	.000000	....	....
53,000	.001833	.000167	.001833	.000167	....	....
54,000	.002000	.000167	.002000	.000167	....	....
55,000	.002333	.000333	.002000	.000000	.000333	.000333
56,000	.002500	.000167	.002000	.000000	.000500	.000167
57,000	.002666	.000166	.002000	.000000	.000666	.000166
58,000	.003333	.000667	.002000	.000000	.001333	.000667
59,000	.004000	.000667	.002167	.000167	.001833	.000509
60,000	.005333	.001333	.002333	.000166	.003000	.001167
61,000	.006166	.000833	.002333	.000000	.003833	.000833
62,000	.007166	.001000	.002500	.000167	.004666	.000833
63,000	.007666	.000500	.002500	.000000	.005166	.000500
64,000	.008333	.000667	.002333	—.000167	.006000	.000834
65,000	.010000	.000667	.002500	.000167	.007500	.001500
66,000	.010500	.000500	.002500	.000000	.008000	.000500
67,000	.011166	.000666	.002666	.000166	.008500	.000500
68,000	.012500	.001334	.002834	.000168	.009666	.001166
69,000	.014166	.001666	.002834	.000000	.011333	.001667
70,000	.014666	.000500	.002834	.000000	.011833	.000500
71,000	.015500	.000834	.003000	.000166	.012500	.000667
72,000	.017333	.001833	.003000	.000000	.014333	.001833
73,000	.018000	.000667	.003000	.000000	.015000	.000667
74,000	.020166	.002166	.003000	.000000	.017166	.001166
75,000	.020833	.000667	.003000	.000000	.017833	.000667
76,000	.021666	.000833	.003333	.000333	.018333	.000500
77,000	.024166	.002500	.003333	.000000	.020833	.002500

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
78, 000	.025166	.001000	.003333	.000000	.021833	.001000
79, 000	.027166	.002000	.003333	.000000	.023833	.002000
80, 000	.028000	.000834	.003500	.000167	.024500	.000667
81, 000	.028666	.000666	.003333	—.000167	.025333	.000833
82, 000	.030000	.001334	.003500	.000167	.026500	.001167
83, 000	.034500	.004500	.003500	.000000	.031000	.004500
84, 000	.035833	.001333	.002667	—.000833	.032166	.001166
85, 000	.039500	.003667	.003834	.001167	.035666	.003500
86, 000	.041833	.002333	.002667	—.001167	.038166	.002500
87, 000	.043166	.001333	.003666	.000999	.039500	.001334
88, 000	.044666	.001500	.004000	.000334	.040666	.001166
89, 000	.050666	.006000	.004000	.000000	.046666	.006000
94, 500	.133333	.082667	....	....	....	....

GENERAL SUMMARY.

Specific gravity	
Tensile strength per square inch ....pounds..	94, 500
Elastic limit ....do....	53, 000
Extension per inch at rupture ....inch..	0. 123
Hardness	
Reduction in diameter at point of rupture ....inch..	0. 175
Original area of cross-section ....square inch..	0. 2481
Area after rupture ....do ...	0. 1176
Position of rupture	about an inch from lower shoulder.
Character of surface	fine fibrous

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 6 *inches long and* 0.562 *inch in diameter, taken from hammered hoop, oil-tempered and annealed.*

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1, 000	0. 000000	0. 000000	0. 000000	0. 000000	....	....
* * *						
11, 000	.000166	.000166	.000166	.000166	....	....
12, 000	.000166	.000000	.000166	.000000	....	....
13, 000	.000166	.000000	.000166	.000000	....	....
14, 000	.000166	.000000	.000166	.000000	....	....
15, 000	.000166	.000000	.000166	.000000	....	....
16, 000	.000166	.000000	.000166	.000000	....	....
17, 000	.000166	.000000	.000166	.000000	....	....
18, 000	.000333	.000167	.000333	.000167	....	....
19, 000	.000333	.000000	.000333	.000000	....	....
20, 000	.000333	.000000	.000333	.000000	....	....
21, 000	.000333	.000000	.000333	.000000	....	....
22, 000	.000333	.000000	.000333	.000000	....	....
23, 000	.000333	.000000	.000333	.000000	....	....
24, 000	.000333	.000000	.000333	.000000	....	....
25, 000	.000333	.000000	.000333	.000000	....	....
26, 000	.000333	.000000	.000333	.000000	....	....
27, 000	.000333	.000000	.000333	.000000	....	....
28, 000	.000500	.000167	.000500	.000167	....	....
29, 000	.000500	.000000	.000500	.000000	....	....
30, 000	.000500	.000000	.000500	.000000	....	....
31, 000	.000500	.000000	.000500	.000000	....	....
32, 000	.000500	.000000	.000500	.000000	....	....
33, 000	.000666	.000166	.000666	.000166	....	....
34, 000	.000666	.000000	.000666	.000000	....	....
35, 000	.000666	.000000	.000666	.000000	....	....
36, 000	.000666	.000000	.000666	.000000	....	....
37, 000	.000666	.000000	.000666	.000000	....	....
38, 000	.000666	.000000	.000666	.000000	....	....
39, 000	.000666	.000000	.000666	.000000	....	....
40, 000	.000833	.000167	.000833	.000167	....	....
41, 000	.000833	.000000	.000833	.000000	....	....

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
42, 000	.000833	.000000	.000833	.000000	....	....
43, 000	.000833	.000000	.000833	.000000	....	....
44, 000	.000833	.000000	.000833	.000000	....	....
45, 000	.000833	.000000	.000833	.000000	....	....
46, 000	.001000	.000167	.001000	.000167	....	....
47, 000	.001000	.000000	.001000	.000000	....	....
48, 000	.001000	.000000	.001000	.000000	....	....
49, 000	.001000	.000000	.001000	.000000	....	....
50, 000	.001000	.000000	.001000	.000000	....	....
51, 000	.001166	.000166	.001166	.000166	....	....
52, 000	.001166	.000000	.001166	.000000	....	....
53, 000	.001166	.000000	.001166	.000000	....	....
54, 000	.001166	.000000	.001166	.000000	....	....
55, 000	.001166	.000000	.001166	.000000	....	....
56, 000	.001166	.000000	.001166	.000000	....	....
57, 000	.001166	.000000	.001166	.000000	....	....
58, 000	.001333	.000167	.001333	.000167	....	....
59, 000	.001500	.000167	.001500	.000167	....	....
60, 000	.001833	.000333	.001667	.000167	.000166	.000166
61, 000	.002000	.000167	.001667	.000000	.000333	.000167
62, 000	.002333	.000333	.001833	.000166	.000500	.000167
63, 000	.002666	.000333	.002000	.000169	.000666	.000166
64, 000	.003833	.000167	.002167	.000167	.001666	.001000
65, 000	.004666	.000833	.002333	.000166	.002333	.000667
66, 000	.005833	.001167	.002333	.000000	.003500	.000167
67, 000	.008000	.002167	.002667	.000334	.005333	.001833
68, 000	.008333	.000333	.002667	.000000	.005666	.000333
69, 000	.008833	.000500	.002667	.000000	.006166	.000500
70, 000	.009666	.000833	.002666	—.000001	.007000	.000834
71, 000	.010333	.000667	.002667	+.000001	.007666	.000666
72, 000	.012666	.002333	.003000	.000333	.009666	.002000
73, 000	.013333	.000667	.003000	.000000	.010333	.000667
74, 000	.014500	.001167	.003000	.000000	.011500	.001167
75, 000	.015000	.000500	.003000	.000000	.012000	.000500
76, 000	.015666	.000666	.003000	.000000	.012666	.000666
77, 000	.018833	.003167	.003000	.000000	.015833	.003167
78, 000	.019833	.001000	.003000	.000000	.016833	.001000
79, 000	.020666	.000833	.008333	.000333	.017333	.000500
80, 000	.022833	.002167	.003333	.000000	.019500	.002167
81, 000	.023666	.000833	.003500	.000167	.020166	.000666
82, 000	.024500	.000834	.003333	—.000167	.021166	.001000
83, 000	.027333	.002833	.003500	.000167	.023833	.002667
84, 000	.029833	.002500	.003667	.000167	.026166	.002333
85, 000	.030333	.000500	.003167	—.000500	.027166	.001000
86, 000	.032000	.001667	.003667	.000500	.028333	.001167
87, 000	.036666	.004666	.003666	—.000001	.033000	.004667
88, 000	.038500	.001834	.003834	.000168	.034666	.001666
89, 000	.039666	.001166	.003833	—.000001	.035833	.001167
90, 000	.045833	.006167	.003833	.000000	.042000	.006167
96, 000	.128666	.072883	....	....	....	....

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds	96, 000
Elastic limit	do	59, 000
Extension per inch at rupture	inch	0. 128
Hardness		
Reduction in diameter at point of rupture	inch	0. 142
Original area of cross-section	square inch	0. 2481
Area after rupture	do	0. 1385
Position of rupture		about an inch from lower shoulder.
Character of surface		the center and one side fibrous; the remainder crystalline.

Table showing the extension, restoration, and permanent set caused by the under mentioned weights per square inch of the primitive section acting upon a solid cylinder 2 inches long and 0.562 inch in diameter, taken from hammered hoop, oil-tempered and annealed.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000	0.000000	0.000000	0.000000	0.000000	....	....
* * * * *						
18,000	.000500	.000500	.000500	.000500	....	....
19,000	.000500	.000000	.000500	.000000	....	....
20,000	.000500	.000000	.000500	.000000	....	....
21,000	.000500	.000000	.000500	.000000	....	....
22,000	.000500	.000000	.000500	.000000	....	....
23,000	.000500	.000000	.000500	.000000	....	....
24,000	.000500	.000000	.000500	.000000	....	....
25,000	.000500	.000000	.000500	.000000	....	....
26,000	.000500	.000000	.000500	.000000	....	....
27,000	.000500	.000000	.000500	.000000	....	....
28,000	.000500	.000000	.000500	.000000	....	....
29,000	.000500	.000000	.000500	.000000	....	....
30,000	.000500	.000000	.000500	.000000	....	....
31,000	.000500	.000000	.000500	.000000	....	....
32,000	.000500	.000000	.000500	.000000	....	....
33,000	.000500	.000000	.000500	.000000	....	....
34,000	.000500	.000000	.000500	.000000	....	....
35,000	.000500	.000000	.000500	.000000	....	....
36,000	.001000	.000500	.001000	.000500	....	....
37,000	.001000	.000000	.001000	.000000	....	....
38,000	.001000	.000000	.001000	.000000	....	....
39,000	.001000	.000000	.001000	.000000	....	....
40,000	.001000	.000000	.001000	.000000	....	....
41,000	.001000	.000000	.001000	.000000	....	....
42,000	.001000	.000000	.001000	.000000	....	....
43,000	.001000	.000000	.001000	.000000	....	....
44,000	.001000	.000000	.001000	.000000	....	....
45,000	.001000	.000000	.001000	.000000	....	....
46,000	.001000	.000000	.001000	.000000	....	....
47,000	.001000	.000000	.001000	.000000	....	....
48,000	.001000	.000000	.001000	.000000	....	....
49,000	.001000	.000000	.001000	.000000	....	....
50,000	.001000	.000000	.001000	.000000	....	....
51,000	.001000	.000000	.001000	.000000	....	....
52,000	.001000	.000000	.001000	.000000	....	....
53,000	.001500	.000500	.001500	.000500	....	....
54,000	.001500	.000000	.001500	.000000	....	....
55,000	.001500	.000000	.001500	.000000	....	....
56,000	.001500	.000000	.001500	.000000	....	....
57,000	.002000	.000500	.002000	.000500	....	....
58,000	.002000	.000000	.002000	.000000	....	....
59,000	.002000	.000000	.001500	—.000500	.000500	.000500
60,000	.003000	.001000	.002000	.000500	.001000	.000500
61,000	.003500	.000500	.002000	.000000	.001500	.000500
62,000	.004500	.001000	.002500	.000500	.002000	.000500
63,000	.005500	.001000	.002500	.000000	.003000	.001000
64,000	.007500	.002000	.002500	.000000	.005000	.002000
65,000	.008500	.001000	.003000	.000500	.005500	.000500
66,000	.008500	.000000	.002500	—.000500	.006000	.000500
67,000	.009000	.000500	.002500	.000000	.006500	.000500
68,000	.010500	.001500	.002500	.000000	.008000	.001500
69,000	.012000	.001500	.003000	+.000500	.009000	.001000
70,000	.012500	.000500	.003000	.000000	.009500	.000500
71,000	.013000	.000500	.003000	.000000	.010000	.000500
72,000	.013000	.000000	.002500	—.000500	.010500	.000500
73,000	.013500	.000500	.002500	.000000	.011000	.000500
74,000	.015500	.002000	.002500	.000000	.013000	.002000
75,000	.016500	.001000	.003000	.000500	.013500	.000500
76,000	.017500	.001000	.003000	.000000	.014500	.001000
77,000	.018500	.001000	.003000	.000000	.015500	.001000
78,000	.020500	.002000	.003500	.000500	.017000	.001500
79,000	.021000	.000500	.003000	—.000500	.018000	.001000
80,000	.022500	.001500	.003500	.000500	.019000	.001000
81,000	.024500	.002000	.003000	—.000500	.021500	.002500
82,000	.026500	.002000	.003000	.000000	.023000	.001500
83,000	.028500	.002000	.003500	.000500	.025000	.002000
84,000	.029500	.001000	.003500	.000000	.026000	.001000
85,000	.030500	.001000	.003500	.000000	.027000	.001000
86,000	.033000	.002500	.003500	.000000	.029500	.002500
87,000	.035000	.002000	.004000	.000500	.031000	.001500
88,000	.036500	.001500	.004000	.000000	.032500	.001500
89,000	.038500	.002000	.004000	.000000	.034500	.002000
90,000	.044500	.006000	.004000	.000000	.040500	.006000

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
91, 000	.047000	.002500	.004500	.000500	.042500	.002000
92, 000	.050000	.003000	.004500	.000000	.045500	.003000
93, 000	.055500	.005500	.003500	—.001000	.052000	.006500
* * * * *						
98, 000	.220000	....	....	....	....	....

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds	98, 000
Elastic limit	do	58, 000
Extension per inch at rupture	inch	0. 22
Hardness		
Reduction in diameter at point of rupture	inch	0. 152
Original area of cross-section	square inch	0. 2481
Area after rupture	do	0. 1820
Position after rupture		at middle.
Character of surface		fine uniform fibrous.

Table showing the extension, restoration, and permanent set caused by the undermentioned weights per square inch of the primitive section acting upon a solid cylinder 2 *inches long and* 0.563 *inch in diameter, taken from hammered hoop, oil-tempered and annealed.*

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1, 000	0. 000000	0. 000000	0. 000000	0. 000000	....	....
* * * *						
9, 000	.000500	.000500	.000500	.000500	....	....
10, 000	.000500	.000000	.000500	.000000	....	....
11, 000	.000500	.000000	.000500	.000000	....	....
12, 000	.000500	.000000	.000500	.000000	....	....
13, 000	.000500	.000000	.000500	.000000	....	....
14, 000	.000500	.000000	.000500	.000000	....	....
15, 000	.000500	.000000	.000500	.000000	....	....
16, 000	.000500	.000000	.000500	.000000	....	....
17, 000	.000500	.000000	.000500	.000000	....	....
18, 000	.000500	.000000	.000500	.000000	....	....
19, 000	.000500	.000000	.000500	.000000	....	....
20, 000	.000500	.000000	.000500	.000000	....	....
21, 000	.000500	.000000	.000500	.000000	....	....
22, 000	.000500	.000000	.000500	.000000	....	....
23, 000	.000500	.000000	.000500	.000000	....	....
24, 000	.000500	.000000	.000500	.000000	....	....
25, 000	.000500	.000000	.000500	.000000	....	....
26, 000	.000500	.000000	.000500	.000000	....	....
27, 000	.000500	.000000	.000500	.000000	....	....
28, 000	.000500	.000000	.000500	.000000	....	....
29, 000	.000500	.000000	.000500	.000000	....	....
30, 000	.000500	.000000	.000500	.000000	....	....
31, 000	.000500	.000000	.000500	.000000	....	....
32, 000	.000500	.000000	.000500	.000000	....	....
33, 000	.000500	.000000	.000500	.000000	....	....
34, 000	.000500	.000000	.000500	.000000	....	....
35, 000	.000500	.000000	.000500	.000000	....	....
36, 000	.000500	.000000	.000500	.000000	....	....
37, 000	.000500	.000000	.000500	.000000	....	....
38, 000	.000500	.000000	.000500	.000000	....	....
39, 000	.000500	.000000	.000500	.000000	....	....
40, 000	.000500	.000000	.000500	.000000	....	....
41, 000	.000500	.000000	.000500	.000000	....	....
42, 000	.000500	.000000	.000500	.000000	....	....
43, 000	.000500	.000000	.000500	.000000	....	....
44, 000	.000500	.000000	.000500	.000000	....	....
45, 000	.000500	.000000	.000500	.000000	....	....
46, 000	.000500	.000000	.000500	.000000	....	....

Table showing the extension, restoration, and permanent set, &c.—Continued.

Weight per square inch of section.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
47,000	.000500	.000000	.000500	.000000		
48,000	.000500	.000000	.000500	.000000		
49,000	.000500	.000000	.000500	.000000		
50,000	.000500	.000000	.000500	.000000		
51,000	.000500	.000000	.000500	.000000		
52,000	.000500	.000000	.000500	.000000		
53,000	.000500	.000000	.000500	.000000		
54,000	.000500	.000000	.000500	.000000		
55,000	.000500	.000000	.000500	.000000		
56,000	.000500	.000000	.000500	.000000		
57,000	.000500	.000000	.000500	.000000		
58,000	.000500	.000000	.000500	.000000		
59,000	.000500	.000000	.000500	.000000		
60,000	.000500	.000000	.000500	.000000		
61,000	.000500	.000000	.000500	.000000		
62,000	.000500	.000000	.000500	.000000		
63,000	.000500	.000000	.000500	.000000		
64,000	.002000	.001500	.000500	.000000	.001500	.001500
65,000	.003000	.001000	.001000	.000500	.002000	.000500
66,000	.004500	.001500	.001000	.000000	.003500	.001500
67,000	.006000	.000500	.001500	.000500	.004500	.001000
68,000	.008000	.002000	.002000	.000500	.006000	.001500
69,000	.009000	.001000	.002000	.000000	.007000	.001000
70,000	.009500	.000500	.002500	.000500	.007000	.000000
71,000	.011500	.002000	.002500	.000000	.009000	.002000
72,000	.012000	.000500	.002500	.000000	.009500	.000500
73,000	.013500	.001500	.003000	+.000500	.010500	.001000
74,000	.015000	.001500	.003500	.000500	.011500	.001000
75,000	.015500	.000500	.003500	000000	.012000	.000500
76,000	.022500	.007000	.003500	.000000	.019000	.007000
77,000	.023000	.000500	.003500	.000000	.019500	.000500
78,000	.023500	.000500	.003500	.000000	.020000	.000500
79,000	.024000	.000500	.003500	.000000	.020500	.000500
80,000	.024000	.000000	.003500	.000000	.020500	.000000
81,000	.024500	.000500	.003500	.000000	.021000	.000500
82,000	.025000	.001000	.003500	.000000	.021500	.000500
83,000	.027000	.002000	.003500	.000000	.023500	.002000
84,000	.030000	.003000	.003500	.000000	.026500	.003000
85,000	.032500	.002500	.003500	.000000	.029000	.002500
86,000	.035000	.002500	.004000	.000500	.031000	.002000
87,000	.037500	.002500	.004500	.000500	.033000	.002000
88,000	.040000	.002500	.004000	−.000500	.036000	.003000
89,000	.043500	.003500	.004000	.000000	.039500	.003500
90,000	.047500	.004000	.004500	.000500	.043000	.003500
91,000	.052500	.005000	.004500	.000000	.048000	.005000
92,000	.059000	.006500	.004000	−.000500	.055000	.007000
93,000	.065500	.006500	.004500	.000500	.061000	.006000
94,000	.072500	.007000	.004500	.000000	.068000	.007000
95,000	.087500	.015000	.005000	.000500	.082500	.014500
96,000	.091500	.004000	.004500	−.000500	.087000	.004500
97,000	.197500	.106000	Broke.			

GENERAL SUMMARY.

Specific gravity		
Tensile strength per square inch	pounds	97,000
Elastic limit	pounds	63,000
Extension per inch at rupture	inch	0.197
Hardness		
Reduction in diameter at point of rupture	inch	0.148
Original area of cross-section	sq. inch	0.24895
Area after rupture	sq. inch	0.1353
Position of rupture	⅔ distance from shoulder.	

Character of surface: rather coarse, dull fibrous structure, mixed toward the outside with small crystals.

APPENDIX 42.

SHRINKAGE TESTS OF STEEL HOOPS FOR CANNON.

BY LIEUT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

(2 plates.)

OFFICE OF INSPECTOR OF ORDNANCE, U. S. A.,
West Point Foundry, Cold Spring, N. Y., October 12, 1883.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

GENERAL: I have the honor to transmit herewith report upon shrinkage tests of the two large steel hoops made pursuant to instructions contained in your letter of July 28, 1883.

The hoops remain in apparently good condition, but are both considerably eccentric and conical on the interior. Highly interesting results as to the "special elasticity" of the metals could be expected from tensile tests of specimens taken from the hoops in their present condition, but in so far as their relative qualities are concerned, the shrinkage tests leave no doubt as to the vast superiority of the oil-tempered hoop up to the point of stretch reached in these tests. Within its proper limits, however, the annealed hoop is excellent.

Very respectfully, your obedient servant,

R. BIRNIE, JR.,
Lieutenant of Ordnance.

Report of experiments made at the West Point Foundry to test the qualities of oil-tempered and untempered Midvale steel gun hoops when applied under shrinkage to a cast-iron body.

INTRODUCTORY—THE NATURE OF THE HOOPS—PHYSICAL QUALITIES OF THE HOOPS AS DETERMINED BY TENSILE TESTS—NATURE OF CAST IRON USED FOR THE CYLINDERS.

THE SHRINKAGE TESTS.

SEC. 1.—Nature of the tests.
2.—Object of the tests.
3.—Preparation of the hoops.
4.—Preparation of the cylinders.
5.—Measurements of the hoops and cylinders.

THE TEST FOR ELASTICITY.

SEC. 6.—*Summary* of measurements of the parts prepared for application.
7.—*The* operation of shrinkage.
8.—*Measurement* of the interior diameters of the hoops in place.
9.—*Final* operations.
10.—*Results* of the test for elasticity.

THE TEST FOR STRENGTH.

SEC. 11.—General description of test, with table of results.

SUMMARY OF RESULTS FROM BOTH THE TESTS.

SEC. 12.—Extension, elastic restoration, and permanent set of the hoops in the elastic test.
13.—Total permanent set of the hoops from the tests combined.
14.—Compression of the cast iron in the two tests and elongation and restoration of the hoops in the strength test.
15.—Elongation of cast-iron cylinder No. 1, due to application of hoops.
16.—Original and developed eccentricity of hoops.
17.—Original and developed conicalness of hoops. Conclusions.

APPENDIX.

Records of measurements pertaining to the test for elasticity:
Tables I, II, III, and IIIa.
Records of measurements pertaining to the test for strength:
Tables IV, V, and VI.

INTRODUCTORY.

Nature of the hoops.—Preliminary to ordering the two steel hoops used in these tests, the Chief of Ordnance, under date of April 3, 1883, addressed a circular letter to steelmakers in the United States, in which, speaking of gun steel, it was stated:

> Open-hearth or Siemens-Martin steel is required. The ingots for the tube and jacket should weigh two and one half times as much as the solid forgings, that the lower and sounder part only of the ingots may be used.
>
> * * * * * * *

And again, after prescribing the physical qualities required for tubes, jackets, and trunnion hoops:

> To obtain these qualities, using a low steel, special treatment will be requisite, the precise steps of which, as well as the most suitable proportion of carbon, must be ascertained by experiment. The general mode of procedure would be thus: After forging, the tube is annealed and specimens for test taken; if satisfactory, it is then rough-bored and turned, and tempered in oil that is kept cool by a current of water, the time of its immersion in the oil being brief; it is then a second time annealed.
>
> The above is the method employed in France and Russia for the treatment of gun steel, and differs, it is believed, from the process followed at the Royal Gun Factory and Sir William Armstrong's works in England, in annealing again after the oil-tempering. Krupp dispenses with oil-tempering altogether, claiming to attain equally good results by covering the ingots, when withdrawn from the mold, with hot ashes, and keeping them so covered for months at a time, allowing the metal to cool very gradually. At the German works of Bochum also, and at Witten, gun steel is not oil tempered, as it is thought the process is attended with too much uncertainty. There steel projectiles alone are tempered in oil. According to the Russian practice, it is stated, the tubes are allowed to remain in the oil tank only ten or fifteen minutes, and are then replaced in the heating furnace, from which the fire has in the mean time been withdrawn, and allowed to cool slowly.
>
> * * * * * * *

In regard to the gun hoops (other than the trunnion hoop), the physical qualities required were stated as follows:

Elastic limit	22 tons.
Resistance at rupture	42 tons.
Elongation at rupture	9 per cent.

> The hoops would best be obtained by rolling, and the preference is given abroad to horizontal rolling-mills (that is, with the hoops in a horizontal position).
>
> In case you possess a tire-rolling mill, the alterations necessary to adapt it to the manufacture of gun hoops should be determined with a view to rolling hoops of twelve

inches width, if desired. A width of seven inches is the least that would be accepted, exclusive of the margin of one and one-fourth inches from which specimens for test are taken.

The hoops also, should the tests made for that purpose prove satisfactory and the operation be attended with certainty, would be oil-tempered. This seems to be the practice at present in Europe, outside of Germany.

* * * * * * *

Of the alternative modes of treatment thus presented in general terms we have here to deal with two, which were applied to hoops manufactured by the Midvale Steel Company.

The Midvale numbers of the two hoops furnished by that company will be retained in this report. They are: No. 9018, which in treatment was *annealed* and *oil-tempered*, and No. 9020, which was simply *annealed*. The latter contains a considerable higher percentage of carbon than the former. Both hoops were rolled.

The hoops were rough-bored and turned at the steel works, and also shortened by taking off there the portions afterwards used for specimen bars which were tested to obtain the tenacity, &c., of the metal under a tensile stress. When received at the West Point Foundry their approximate dimensions were:

Hoops.	Interior diameter.	Exterior diameter.	Thickness.	Length.	Weight.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Pounds.*
No. 9018 oil-tempered	45.5	53.5	4	5.625	2,012
No. 9020, annealed	45.25	53.5	4.125	5.625	

As regards the diameters, these dimensions are nearly equal to the largest hoops that will be required for the experimental guns, viz: the exterior row of the 12-inch cast-iron hooped gun on the French plan.

Physical qualities of the metal as determined by tensile tests.—These tests were made preliminary to the shrinkage tests, to ascertain especially the extension, per linear unit, of the metal at the elastic limit, and hence obtain by direct means the shrinkage to be given in those tests. The tensile tests were made by Lieut. C. W. Whipple, U. S. Ordnance, upon the testing machine at the proving ground, Sandy Hook, N. J. Specimen bars of 2, 3, 6, and 8 inches length between shoulders were taken from portions of the hoops cut off at Midvale after their manufacture. At date the results of the 2 and 3 inch specimens alone are available, of which those of 3 inches length are taken as a basis for this report.

The following table gives the *mean* results of the mechanical tests of 4 bars from each hoop:

TABLE A.

Subject of measurement.	Hoop No. 9018, oil-tempered.	Hoop No. 9020, annealed.
Number of specimens tested	4	4
Length of specimens between shoulders:		
Original ... inches	3	3
After rupture ... do	3.5815	3.5355
Diameter of specimens:		
Original ... inches	0.5605	0.56225
After rupture ... do	0.40675	0.48975
Elastic limit ... pounds	56,250	46,250
Extension per linear unit at elastic limit ... thousandths	2.4166	1.5
Ultimate resistance per square inch of original area ... pounds	99,250	102,500
Ultimate extension per linear unit ... thousandths	193.844	178.5
Ratio of elastic to ultimate resistance	1.764	2.216
Original area of cross-section ... square inches	0.24675	0.2483
Contraction of area at fracture ... per cent	47.33	24.126
Ultimate resistance per square inch of fractured area ... pounds	188,460	135,100

FRACTURE OF SPECIMENS.

	Specimen number.	Position.	Character of surface.
Hoop No. 9018, oil-tempered.	1	Near middle	Crystalline, with core of rather loose, dark gray structure.
	2	One-third from shoulder.	Fine, uniform, silky structure.
	3	Near middle	Uniform, but rather coarse, fibrous structure.
	4	......do	Crystalline, with dull gray core.
Hoop No. 9020, annealed.	1	One-third from shoulder.	Uniform, crystalline structure, except one small spot.
	2	Near middle	Compact, crystalline, with small dull gray spot on one side.
	3	One-third from shoulder.	Uniform, crystalline, with small dull spot on one side.
	4	......do	Crystalline, with small dull gray spot on one side.

The average results from the 2-inch specimens show a lower elastic limit than the 3-inch, but the latter must be considered the more trustworthy for the purpose of this report.

Nature of the cast-iron used in the tests.—As the tests were to be conducted with the special object of determining the *relative* value of the tempered and untempered steel hoops, and as these were to be shrunk upon cylinders taken from the same casting, it was not deemed important to make preliminary tests of the cast-iron.

The cylinders used were taken, however, from the body between the bottom of the bore and the trunnions of 15-inch Rodman (smooth bore) gun No. 80, manufactured by C. Alger & Co., South Boston, Mass., in 1865. In cutting out the cylinders the metal was found to be of excellent quality throughout the thickness of the walls of the gun. The cylinders may therefore be said to constitute a very fine quality of gun metal, having, at the least, the following physical properties: tenacity, 30,000 pounds, and elastic limit, 12,000 pounds per square inch; relative extension at elastic limit under stress 0.6 thousandths, and compression at the elastic limit under stress 1.0 thousandths of the linear unit.

THE SHRINKAGE TESTS.

SECTION 1. *Nature of the tests.*—As directed by the Chief of Ordnance, two distinct tests of the hoops were made.

1. The test for *elasticity*, in which the hoops, after being carefully prepared, were shrunk upon a hollow cast-iron cylinder with a prescribed shrinkage intended to produce in the hoops a tension equal to or a little greater than that corresponding to the elastic limit of their metal.

2. The test for *strength*, in which the hoops, taken in the condition in which they were left by the first test, were shrunk upon a hollow cast-iron cylinder with a shrinkage double that used in the first test.

SEC. 2. *Object of the tests.*—This was to ascertain primarily the *relative* (and absolute) behavior of tempered and untempered steel hoops, when applied under shrinkage to a cast-iron body. For this purpose the following observations were made:

IN THE TEST FOR ELASTICITY.

1. The compression of the bore of the cast-iron cylinder with the hoops applied.

2. The momentary elongation of the interior diameter of the hoops in place; that is, their extended diameters whilst applied.

3. The compression of the exterior of the cast-iron *cylinder with* the hoops applied.
4. The elongation of the cast-iron cylinder with the hoops applied.
5. The elastic restoration of the hoops on removal of the cylinder.
6. The permanent set of the hoops after the cylinder was removed.

IN THE TEST FOR STRENGTH.

1. The compression of the bore of the cast-iron cylinder with the hoops applied.
2. The restoration of the hoops on removal of the cylinder.
3. The permanent set of the hoops after the cylinder was removed.
4. The condition of the hoops at the conclusion of the test; that is, whether any flaws or cracks had been developed.

In both tests the cast-iron cylinders were cut out from the hoops, thus precluding any observations as to the permanent set of the cast iron.

SEC. 3. *Preparation of the hoops.*—These were finished before the cast-iron cylinders. As the two hoops were to be finished to identical dimensions throughout, and since it was desirable to retain their dimensions as large as practicable, No. 9018, having the greater interior diameter and hence the least surplus metal, was prepared first. In finishing the hoops great care was taken to make the interior very smooth and true; they were also carefully turned on the exterior and faced at both ends.

A marked difference was observed in the working (turning, boring, and facing) of the metal of the two hoops. The time occupied in finishing each was: No. 9018, twenty-six hours; No. 9020, thirty-one hours, a difference of five hours in favor of the oil-tempered hoop. This hoop is of nearly uniform hardness, and no particular difficulty was experienced in working it, other than the wear of the tool in finishing the bore; this necessitated three finishing cuts in order to straighten the bore, the last two of which were very light.

The annealed hoop, on the contrary, is much harder generally, and frequent *hard spots* were met with, which wore away the cutting tool very rapidly. In this hoop, also, three finishing cuts were taken on the interior, and in addition several light passes of the tool over particular parts, to straighten the bore. The tools used with the oil-tempered hoop were found to be too soft for this, and a special tool was made, the edge of which was hardened by using powdered yellow prussiate of potash.*

Considering the difference of time alone occupied in finishing these particular hoops, weighing about 1,000 pounds each, it appears that the cost of the annealed ring was relatively increased $7.50, or about 7.5 mills per pound.

The metal removed in finishing hoop No. 9018 (the least) was about 0.065 inch from the thickness on the interior, and 0.055 inch on the exterior, while from each face about 0.0625 inch was taken. This reduction of metal may be taken as the least possible under favorable circumstances, for the hoop as received was rough-bored and turned, and consequently true.

In their finished state the hoops weighed: No. 9018, 945 pounds; No. 9020, 943 pounds; total, 1,888 pounds; giving a total loss of weight, for the two, equal to 124 pounds.

SEC. 4. *Preparation of the cylinders.*—After the hoops had been prepared and their interior diameters measured, then, with the prescribed shrinkage known, the cast-iron cylinders for both the tests were made ready.

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* Potassium ferrocyanide—a well-known application for the case-hardening of small steel articles.

To insure a just comparison of the merits of the two hoops it was deemed best to shrink both hoops upon the same cylinder; this gave an additional advantage in economy, since it required the preparation of but one cylinder for each test of the two hoops. In order, however, to preserve their influence distinct, an interval of about 0.75 inch was left between them. The cylinders also were designed to project 0.125 inch from the outside of the hoops, with a view to securing uniformity of resistance in the cast iron throughout the bearing of each hoop (see Figs. 1, 2, and 3, Plate I). This called for a length of about 12.075 inches for each of the cylinders.

In preparing them, the old gun—the breech of which had already been cut off for another purpose—was mounted in a lathe and rough-turned over the length of the two cylinders. Cuts were then taken nearly to the bore to separate the cylinders; after which both were finished in place on the outside. They were then successively faced at the rear, finished-bored, cut off, and placed on the face-plate of the lathe for facing at the other end. They will be herein designated as:

Cast-iron test cylinder No. 1; to be used in the test for elasticity.

Cast-iron test cylinder No. 2; to be used in the test for strength.

SEC. 5. *Measurements of the hoops and cylinders.*—When prepared for application, a number of interior diameters of the hoops were measured to obtain the mean of each and also to ascertain whether their interior was perfectly cylindrical; their thickness and length were also measured, verifying at the same time the parallelism of their faces both plain and curved.

In the cylinders also a number of interior diameters were measured, and as far as practicable the thickness corresponding to the extremities of each interior diameter from which the exterior diameters were obtained. These interior and exterior diameters were then grouped for each half of the cylinder, and treated separately for the hoops which covered them. In addition to this, cylinder No. 1 was measured for length at a number of points on the circumferences of three circles, one near the bore, another about the middle of the thickness of its walls, and another near the outer edge.

The measurements were all made to correspond accurately with the standard vernier-gauge of the office. The interior diameters were measured with an iron rod or "point," having at one end an adjustable point secured by a clamp-screw, the setting of which for each diameter was measured with the vernier-gauge. The thicknesses and lengths were measured with vernier diameter calipers. In this way all the measurements recorded were taken with instruments graduated to read to the thousandth part of an inch.

To facilitate the work, and in order to insure that successive measurements of the parts should be taken at identical points throughout the several periods of the tests, four diameters were *scored* and numbered on the faces of each hoop and cylinder, dividing the circumference into eight equal parts, and measurements were taken in the axial plane of each of these to determine the several mean diameters at points on the length of the hoop or cylinder measured.

In the Appendix, Tables I, II, III, IV, V, VI, is recorded the measurements in detail of the hoops and cylinders when prepared for application; the bores of the cylinders with the hoops applied, and of the hoops after removal from the cylinders. The summaries with the several tables show either the permanent set of the hoops or the compression of the bore of the cylinders with the hoops applied. (See also Figs. 1 and 2, Plate II.)

THE TEST FOR ELASTICITY.

SEC. 6. At this point we will summarize only the measurements of the parts when prepared for application, in the test for elasticity:

TABLE B.—*Test for elasticity* (*hoops and cast-iron cylinder No.* 1, *prepared for application.*)

Measurements.		Hoop No. 9018.	Hoop No. 9020.	Cast-iron test cylinder No. 1.				
				Under hoop No. 9018.		Under hoop No. 9020.		Length.
		Interior.	Interior.	Interior.	Exterior.	Interior.	Exterior.	
Single diameters	number	20.	20.	24.	16.	20.	12.	....
Difference between greatest and least diameter measured	inches	0.004	0.005	0.00975	0.0085	0.0135	0.0125	....
Mean diameters (in sets of 4)	number	5.	5.	6.	4.	5.	3.	....
Eccentricity or maximum difference observed in any set of 4 diameters,	inches	0.003	0.002	0.006	0.00775	0.008	0.008	....
Mean eccentricity or greatest difference between the means of the measurements taken on the 4 series of diameters	inches.	0.0019	0.0013	0.0052	0.00669	0.006	0.0078	....
Conicalness or maximum difference observed between any two mean diameters	inches.	0.0016	0.00425	0.0044	0.00144	0.006875	0.00475	....
Grand mean diameters	do	45.6303	45.629775	18.40341	45.71723	18.399425	45.71646	....
Actual shrinkage, or difference between mean exterior diameter of cylinder and mean interior diameter of hoop.	thousandths*	1.905	1.899	....	....	....	....	....
	inches	0.08693	0.08668	....	....	....	....	....
Mean shrinkage prescribed for the test.	thousandths	1.75	1.75	....	....	....	....	....
	inches	0.07985	0.07985	....	....	....	....	....
Excess of actual over prescribed shrinkage.	thousandths	0.155	0.149	....	....	....	....	....
	inches	0.0071	0.00683	....	....	....	....	....
Separate measurements taken, number		....	....	....	....	....	....	24.
Mean length of cylinder	inches	....	....	....	....	....	....	12.07596

* Expresses the elongation, per linear unit, of the mean interior diameter (or circumference) of the hoop for the shrinkage or difference stated.

These results show that the work was done within recognized limits of accuracy, except for the shrinkage, for which the limits of 1.7 to 1.8 thousandths of the mean interior diameter of hoop had been fixed; these limits having been determined, as before intimated, from the tensile tests of the metal. By those tests the elongation, per linear unit, at the elastic limit was determined: for hoop No. 9018, 2.4165 thousandths, and for hoop No. 9020, 1.5 thousandths. Therefore, in prescribing the above limits or a mean shrinkage of 1.75 thousandths, an approximate average was taken of the elastic elongation of the two hoops. This gave a relatively excessive strain for the annealed hoop (No. 9020), which was further increased by the actual shrinkage given.

SEC. 7. *The operation of shrinking on the hoops.*—Cast-iron cylinder No. 1 was leveled end on, and slightly raised from an iron plate somewhat larger in circumference than the cylinder. The opening between the cylinder and plate was calked so as to allow the outflow of a portion only of the water which was run into the bore (as soon as the first hoop was put on) through an inch hose, the object being to keep the bore of the cylinder constantly filled with cold water. Thin strips of iron of equal thickness were placed on the plate around the outside of the cylinder, upon which to rest the first hoop put on and keep it leveled with its lower edge 0.125 inch from the lower end of the cylinder. Other blocks of iron, about 0.8 inch thick, were also provided, to lay on the first hoop, after its shrinkage, and provide a rest for the second hoop so as to keep it leveled with its upper edge 0.125 inch from the upper end of the cylinder. An iron rod or point with a long handle attached at the middle was also provided to test from time to time the expansion of the hoops whilst heating. This point was made about 0.05 inch longer than the exterior diameter of the cylinder, it being considered that an expansion of the hoop equal to this—about 3.0 thousandths, per linear unit, of the mean interior diameter of the hoops, or 1.1 thousandth greater than that corresponding to the shrinkage—would be the greatest that the hoops could stand with safety in this test, even though the expansion were caused by heat. This excess was moreover considered sufficient for the placing of the hoops.

The hoops were heated in a wood fire in the open air. They were arranged for the purpose (laid flat) about fifteen inches from the ground, resting on three open cast-iron boxes. Small cord-wood was then piled within and without the hoop—resting on end without—until the hoop was concealed by it. The charge of wood was about three-tenths of a cord. This arrangement gave a serious inconvenience, in that the expansion of the hoops could not be measured without scattering the fire or else waiting until the charge had burned down. But since the workmen were experienced in this method—the Parrott gun bands particularly having at one time been applied in this way—and since a wood fire used in this way was considered the least hurtful fuel that could be applied, it was decided to use the method as the best available.

As soon as the first hoop was placed on the cylinder the water was turned into the bore and kept running until all the parts were cool enough to bear the hand. This was repeated for each hoop. After each hoop had been placed it was allowed to cool slowly until it had clamped the cylinder; water was then thrown lightly upon it until its temperature was reduced to about that of boiling water (212° F), after which the hose was turned upon it until it was nearly cold.

But little heat was developed in the cast iron. The outer portion—in contact with the hoops—at no time reached a temperature sufficient to make the water boil, whilst the inner half, approximately, of the thickness of the cylinder, remained cool throughout.

The following tabular statement exhibits the record of the heating operations. Hoop No. 9020 was heated first:

Observations recorded.	Hoop No. 9018.	Hoop No. 9020.
Time from lighting fire until withdrawal	45 minutes	1 hour 15 minutes
[*] Expansion (approximate) above original mean interior diameter. inches	0.3	0.38
thousandths	6.5746	8.328
Time from application of hoop until it closed on the cylinder	45 minutes	45 minutes
Time from application of hoop until it was cooled with water.	50 minutes	50 minutes
Time during which water was run into the bore of the cylinder.	1 hour 30 minutes	1 hour 20 minutes

It will be seen that the expansion of the hoops was excessive; the oil-tempered hoop (No. 9018) being extended to about 2.7 times, and the annealed hoop to about 5.5 times the elastic limit of its metal in a cold state. It is interesting to note, however, that their subsequent behavior goes far towards proving that they were not injured by this. Seen in the daylight, neither of the hoops were heated to redness.*

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[*] This measurement was obtained as soon as the hoop was placed on the cylinder, when the space between the cylinder and hoop was measured as carefully as possible with an ordinary rule.

SEC. 8. *Measurement of the interior diameters of the hoops in place.*—When steel hoops are expanded by heat and applied with shrinkage to a body of metal—as in the present case, or in gun construction—the contractile force of the hoops, on cooling, is exerted to compress the inner body, in which process it meets with a resistant force increasing proportionately to the compression induced. After the parts have become cool and a certain length of time (probably not more than 24 hours) has relapsed, the forces acquire a state of equilibrium, and the hoops will remain, until this equilibrium is destroyed by some extraneous cause, in a state of elongation which will be less than that corresponding to the shrinkage prescribed in proportion as the inner body is compressed. We then determine this definite (momentary) elongation by measuring the interior diameter of the hoops in place, from which it will be apparent whether or not the shrinkage has been excessive for any particular hoop by observing whether or not its metal is elongated beyond its elastic limit. In testing simply the relative qualities of any two given hoops applied to the same inner body we arrive at a measure of their total contractile force by measuring the contraction of the bore of the inner body under each in place. And by measuring the interior diameters of the hoops themselves in place we further arrive at an essential knowledge of the limit of useful shrinkage for any particular quality of hoop metal, the approximate resistance of the inner body to compression being supposed known. By these latter measurements we also make the shrinkage tests approximately comparable with the tensile tests, for, knowing the actual elongation of the hoops in place, we find their elastic restoration from that stretch by measuring the permanent set of the hoops after the removal of the inner body.

For measuring the interior diameters in place of the two hoops tested, grooves 0.625-inch wide and about 0.25-inch deep, were made 68 hours after the shrinkage in each end of the cylinder along the four diameters marked in figs. 1 and 3, Plate I. By this means one set of the same diameters that had been measured before the shrinkage was exposed on the interior of the hoop. These diameters were then measured in the same way as before, with the following results:

Interior diameters of hoops in place.	Distance from top of hoop.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Means.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
No. 9018, oil-tempered	0.1	45.705	45.6995	45.7025	45.7045	45.702875
No. 9020, annealed	0.1	45.7005	45.704	45.7025	45.6995	45.701625

From the two mean diameters thus determined, being one set taken near the top only of each hoop, the grand mean diameter for each hoop in place was deduced by taking the elastic restoration, which was determined after the cylinder was removed and when the permanent set was measured for each of these diameters, as the constant elastic restoration for the hoop to which it belonged, that is, by assuming that the elastic restoration throughout each hoop was uniform on removing the cylinder, and adding it to the grand mean interior diameter of the hoop as measured for permanent set.

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* If we estimate the temperature corresponding to this expansion by the rule (applicable to comparatively low temperatures) that the metal should elongate 1.15-thousandths, per linear unit, for every 212° F. of temperature, we find for the temperature of the oil-tempered hoop (No. 9018) about 1200° F., and for the other hoop about 1500° F., results which may be set down as widely erroneous, since *iron, red hot, visible in daylight,* should have a temperature of about 1100° F. (Enc. Brit., article "Iron," and Knight's Mechanical Dictionary, "Fusing Points.") It is probable that the temperature of the annealed hoop (No. 9020) approached nearly the temperature of "iron, red hot, visible in daylight," but it did not reach it.

The following table shows the values determined as above:

Table C.

Interior of hoops.	No. 9018.	No. 9020.
	Inches.	*Inches.*
Mean diameter in place at 0.1 inch from top	45. 702875	45. 701625
Same diameter as measured for permanent extension	45. 63175	45. 635625
Difference equals elastic restoration on this mean diameter (supposed constant throughout each hoop)	0. 071125	0. 066
Grand mean diameter as measured for permanent set	45. 63235	45. 640725
Grand mean diameter of hoop in place	45. 703475	45. 706725

These values, which give also the exterior of the cast-iron cylinder with the hoops in place—for the two surfaces were in contact—will be found in the general table (D) which follows.

SEC. 9. *Final operations:*—Twenty-four hours after the shrinkage the bore of the cylinder was measured, and also its length at the same points as before, in order to determine its compression and total extension with the hoops applied (see Tables III and III*a* Appendix).

The cylinder was removed from the hoops by taking three cuts in a vertical slotting machine, from the bore outwards. Great care was taken in this operation to preserve the interior of the hoops from injury. But little hand work was required, however, since the thin layers of metal left by the machine were broken by the contraction of the hoops.

The hoops were relieved from strain about 84 hours after the shrinkage, but not entirely cleared from the cylinder until 96 hours. The interior of both hoops was then measured at the same points as before the shrinkage in order to determine their permanent set (see Tables I and II Appendix), which, taken in connection with their interior diameters in place, gave also the elastic restoration for each, and as well the restoration corresponding to the shrinkage given.

SEC. 10. *Results of the test for elasticity.*—The mean results of the measurements taken are given in the following table. The (relative) differences, "expressed in *thousandths* of the unit of length," are given for the *fibers* at the surface of each part, to express as clearly as may be what is actually implied by the corresponding differences "measured on the diameters" and expressed in inches, the relative elongation or contraction of the circumferences being the same as that of the diameters:

TABLE D.—*Test for elasticity (cast-iron cylinder No. 1).*

Subjects of measurement.	Hoop No. 9018, oil-tempered.	Hoop No. 9020, annealed.
DIMENSIONS OF THE PARTS.		
Prepared for application.	*Inches.*	*Inches.*
Length of hoop	5.5	5.5
Thickness of hoop	3.88	3.88
Ratio of circumferential section of hoop to corresponding section of cast-iron cylinder	2.26	2.26
Mean interior diameter of hoop	45.6303	45.629775
Mean exterior diameter of cast-iron cylinder	45.71723125	45.7164625
Mean interior diameter of cast-iron cylinder	18.40340625	18.399425
With the hoops applied.		
Mean interior diameter of hoop	45.703475	45.706725
Mean exterior diameter of cast-iron cylinder	45.703475	45.706725
Mean interior diameter of cast-iron cylinder	18.389021	18.386521
After removal from the cylinder.		
Mean interior diameter of hoop	45.63235	45.640725
DIFFERENCES.		
Measured on the diameters.		
Shrinkage, or excess of exterior diameter of cylinder over interior diameter of hoop	0.08693125	0.0866875
Extension of interior diameter of hoop in place	0.073175	0.07695
Contraction of exterior diameter of cylinder in place	0.01375625	0.0097375
Contraction of interior diameter (bore) of cylinder in place	0.0143853	0.012904
Elastic restoration of interior diameter of hoop on removal from cylinder	0.071125	0.066
Permanent set or extension of original interior diameter of hoop when removed from cylinder	0.00205	0.01095
Difference between shrinkage and permanent set of hoop	0.08488125	0.0757375
Expressed in thousandths of the unit of length.	*Thousandths.*	*Thousandths.*
Elongation of interior fibers of hoop corresponding to shrinkage given	1.9051	1.8998
Actual elongation of interior fibers of hoop in place	1.6036	1.6864
Compression of exterior fibers of cylinder in place	0.3009	0.213
Compression of interior fibers (bore) of cylinder in place	0.78167	0.70133
Elastic restoration of interior fibers of hoop on removal from cylinder	1.5587	1.4464
Permanent elongation or set of interior fibers of hoop when removed from cylinder	0.0449	0.24
Restoration of interior fibers of hoop corresponding to difference between shrinkage and permanent set of hoop	1.8602	1.6598

THE TEST FOR STRENGTH.

SEC. 11. This test was conducted in the same manner as the test for elasticity, except that neither the length of the cylinder nor the interior diameters of the hoops in place were measured.

The hoops were used in the state in which they were left by the test for elasticity.

The cast-iron test cylinder (No. 2) used in this test was, as before stated, prepared at the same time as No. 1. The bores of the two cylinders were intended to be identical, and the exterior of No. 2 was calculated so as to make the shrinkage in this test 3.5 thousandths per linear unit of the original interior diameter of the hoops, or twice the mean shrinkage prescribed for the test for elasticity. Referring to Tables IV, V, and VI, Appendix, the following table exhibits a summary of the measurements of the parts when prepared for application:

TABLE E.—*Test for strength (hoops and cast-iron cylinder, No. 2, prepared for application).*

Measurements.		Hoop No. 9018.	Hoop No. 9020.	Cast-iron test cylinder No. 2.			
				Under hoop No. 9018.		Under hoop No. 9020.	
		Interior.	Interior.	Interior.	Exterior.	Interior.	Exterior.
Single diameters.........number		20	20	24	20	24	16
Difference between greatest and least diameter measured inches		0. 019	0. 0305	0. 008	0. 008	0. 006	0. 011
Mean diameters (in sets of 4), number		5	5	6	5	6	4
Eccentricity or maximum differences observed in any set of 4 diameters		0. 016	0. 0185	0. 004	0. 006	0. 005	0. 007
Mean eccentricity ....inches		0. 015	0. 0179	0. 0032	0. 0042	0. 0025	0. 00625
Conicalness or maximum difference observed between any two mean diameters .... inches		0. 0031	0. 0119	0. 004	0. 002	0. 003	0. 0055
Grand mean diameters ......do		45. 63235	45. 640725	18. 39621	45. 797404	18. 397792	45. 79419$_6$
Actual shrinkage	thousandths	3. 6172	3. 3634	Estimated on diameters given.			
	inches	0. 165054	0. 153471				
Shrinkage prescribed for the test estimated on original interior diameter of hoop.	thousandths	3. 5	3. 5				
	inches	0. 1597	0. 1597				
Excess of actual over prescribed shrinkage.	thousandths	0. 1172	−0. 1366				
	inches	0. 005354	−0. 00623				

It will be observed that the measurements given in this table for the interior of the hoops are taken after the hoops had received the permanent set induced by the test for elasticity. The cylinder was turned slightly larger on the exterior than was prescribed. The prescribed shrinkage of 3.5 thousandths, which was calculated on the original interior diameter of the hoops should have been actually less than that in this test, because both interior diameters were somewhat extended. We perceive, however, that the actual shrinkage exceeded the prescribed for the oil-tempered hoop, whilst it was less than the prescribed for the annealed hoop. The latter hoop was, therefore, the least severely tried in this test, assuming that its elastic properties were not injured by the test for elasticity, from which it received a greater permanent set than the oil-tempered hoop.

Profiting by the experience gained in heating the hoops for the former test, the application of them in this test was accomplished without an excessive expansion. The hoops were heated in the same way, but were not allowed to remain as long in the fire as before.

The oil-tempered hoop was heated first. It was withdrawn 32 minutes after the fire had been lighted, and when placed on the cylinder showed an expansion of about 0.125 inch greater than the exterior of the cylinder.

The annealed hoop was withdrawn 27 minutes after the fire had been lighted. Its expansion above the exterior of the cylinder was about 0.1 inch. Both hoops were therefore actually less expanded by the heat when applied in this test than when applied in the test for elasticity, although the cylinder in this test was nearly 0.1 inch larger. The surplus expansion of the annealed hoop came very near the minimum limit allowable, that was 0.1 inch play, for the application.

The two hoops were placed on one cylinder as before, the arrangement being shown in figs 1, 2, and 3, Plate I.

Twenty-four hours after the hoops had been applied the bore of the cylinder was remeasured for compression (see Table VI, Appendix).

The cylinder was cut out from the hoops within 72 hours after the application, and the hoops were then finally measured for permanent extension.

The following table, abstracted from Tables IV, V, and VI, Appendix, gives the mean results determined by this test:

TABLE F.—*Test for strength* (*cast-iron cylinder No. 2*).

Subjects of measurement.	Hoop No 9018, oil-tempered.	Hoop No. 9020, annealed.
DIMENSIONS OF THE PARTS.		
Prepared for application.		
	Inches	*Inches.*
Mean interior diameter of hoop	45. 63235	45. 640725
Mean exterior diameter of cast-iron cylinder	45. 797404	45. 794196
Mean interior diameter of cast-iron cylinder	18. 39621	18. 397792
With the hoops applied.		
Mean interior diameter of cast-iron cylinder	18. 3751875	18. 380271
After removal from the cylinder.		
Mean interior diameter of hoop	45. 6815	45. 695275
DIFFERENCES.		
Measured on the diameters.		
Shrinkage, or excess of exterior of cylinder over interior diameter of hoop	0. 165054	0. 153471
Contraction of interior diameter (bore) of cylinder in place	0. 021021	0. 017521
Permanent set or extension of mean interior diameter of hoop when removed from cylinder	0. 04915	0. 05455
Restoration or difference between shrinkage and permanent set of hoop	0. 1159	0. 098921
Expressed in thousandths of the unit of length.		
	Thousandths.	*Thousandths.*
Elongation of interior fibers of hoop corresponding to shrinkage given	3. 617	3. 3626
Contraction of interior fibers (bore) of cylinder in place	1. 144	0. 95325
Permanent elongation or set of interior fibers of hoop when removed from cylinder	1. 077	1. 1952
Restoration of interior fibers of hoop corresponding to shrinkage given	2. 54	2. 1674

SUMMARY OF RESULTS FROM THE TESTS.

SEC. 12. In considering the relative behavior of the two hoops it must be borne in mind that although they were of the same dimensions, and were applied with practically equal shrinkages, to the same cast-iron body, yet the annealed hoop was relatively more severely tested than the oil-tempered one; the former having, as determined by the tensile tests, an elongation per linear unit at the elastic limit of but 1.5 thousandths, as compared with 2.4165 thousandths for the latter; and, moreover, by the shrinkage given in the *elastic* test, this elastic elongation was exceeded in the one, whilst it was not reached in the other. That the annealed hoop should have come out of this test with so little permanent set—0.24 thousandth of its mean interior diameter—speaks well for its quality.

As to the actual extension produced in the two hoops by the shrinkage given in the elastic test, which was determined by measuring the interior diameters of the hoops in place (sec. 8), we take from Table D the following: For the oil-tempered hoop, 1.6036 thousandths per linear unit; for the annealed hoop, 1.6864 thousandths per linear unit, which, compared with the records of the tensile tests, show that the elastic limit of the oil-tempered hoop was not reached, whilst that of the annealed hoop was exceeded to the amount of 0.1864 thousandth per linear unit; or, its actual elongation corresponded to a load of

47,200 pounds per square inch in the tensile tests, about 1,000 pounds per square inch greater than the load at the elastic limit.

When the cylinder was removed from the hoops in the elastic test we find the elastic restoration of the two hoops to have been: Oil-tempered, 1.5587 thousandths per linear unit; annealed, 1.4464 thousandths per linear unit, and that the permanent set was 0.0449 and 0.24 thousandth per linear unit respectively. A result so small for the oil-tempered hoop that it may be questioned whether it may not have been due to the heating of the hoop alone, and for the annealed hoop sufficiently small to indicate that the hoop was not injured by the test.

Comparing these elastic restorations with those observed in the tensile tests we find:

Elongations per linear unit.

	Extension, under load.	Restoration, load removed.	Permanent set.
Tensile tests:	*Thousandths.*	*Thousandths.*	*Thousandths.*
Specimens from oil-tempered hoop	1.6036	1.6036	0.
Specimens from annealed hoop	1.6864	1.5	[*]0.1864
Shrinkage tests:			
Oil-tempered hoop	1.6036	1.5587	0.0449
Annealed hoop	1.6864	1.4464	0.24

[*] Mean result taken from the records of tensile tests of the four specimen bars, 3 inches in length between shoulders.

Viewing these results for the annealed hoop, which was extended beyond its elastic limit, we find a remarkable coincidence between the results of the two distinct series of tests, tensile and shrinkage. There is, in fact, a difference of 0.0535 thousandth in the restoration of this hoop per linear unit, as determined by the distinct tests, against a similar difference of 0.0449 thousandth for the oil-tempered hoop which was not stretched to its elastic limit in the shrinkage test, and for which this difference, the permanent set, must be attributed to a cause inherent in the shrinkage test. Assuming that the same cause acted upon the annealed hoop to produce a similar effect, we find the two distinct tests not only confirmatory but almost identical in their results.

SEC. 13. After the removal of the cylinder in the strength test, the permanent set, estimated on the *original* mean interior diameters, that is, the total permanent set due to the two tests combined, was respectively: For the oil-tempered hoop, 1.07724 thousandths per linear unit; for the annealed hoop, 1.1955 thousandths per linear unit, whilst the restoration on this removal, taken as the difference between the *shrinkage* and the permanent set, and estimated on the mean interior diameters of the hoops as applied in this test, was: For the oil-tempered hoop, 2.54 thousandths per linear unit; for the annealed hoop, 2.167 thousandths per linear unit.

SEC. 14. The compression of the cast-iron test cylinders by the hoops in the two tests was as follows:

Compression of cylinders in thousandths of original diameters.

	Under the oil-tempered hoop.	Under the annealed hoop.
Elastic test, cylinder No. 1:	*Thousandths.*	*Thousandths.*
Mean interior diameter	0.78167	0.70133
Mean exterior diameter	0.3009	0.213
Excess of compression at interior over exterior	0.48077	0.48833
Strength test, cylinder No. 2:		
Mean interior diameter	1.144	0.95325
Mean exterior diameter	Not measured	Not measured

If we assume that the difference between the interior and exterior compression of the cylinder was the same in the strength test as in the elastic test, the difference in thickness of the cast-iron wall in the two cases was less than 0.05 inch, we find the compression of the exterior of the cylinder (No. 2) in the strength test: Under the oil-tempered hoop, 0.6633 thousandth per linear unit; under the annealed hoop, 0.46492 thousandth per linear unit, from which we deduce the diameters of the hoops *in place* in the strength test, as: Oil-tempered hoop, 45.76702 inches; annealed hoop, 45.7729 inches, giving an elongation per linear unit estimated on the *original* interior diameters: Oil-tempered hoop, 2.9962 thousandths; annealed hoop, 3.137 thousandths.

From the diameters as *applied* in the strength test we deduce an elongation of 2.9512 and 2.896 thousandths per linear unit respectively, as compared with 3.617 and 3.3626 thousandths taken from the shrinkage given without considering the compression of the cast iron under the hoops in place. Again, we find from our deduction the elastic restorations in the strength test, estimated on the interior diameter of the hoops as applied, on removal of the cylinder, to have been: In the oil-tempered hoop, 1.874 thousandths per linear unit; in the annealed hoop, 1.7006 thousandths per linear unit, as compared with 2.54 and 2.167 thousandths respectively, estimated from the shrinkage given.

These results evince the marked superiority of the oil-tempered hoop, both in elastic properties and in contractile force.

SEC. 15. The measurements taken of the length of cast-iron test cylinder No. 1, before the application of the hoops, and again with the hoops applied, in the elastic test, gave very uniform results (see Table III*a*, Appendix). Of the twenty-four measurements taken all showed an extension, with the hoops applied, except two. The mean extension determined was 0.00275 inches, or an elongation of 0.228 thousandths, per linear unit, estimated on the original length (12.07596 inches) of the cylinder.

SEC. 16. Both hoops were rendered eccentric by the tests, and in addition assumed a conical shape on the interior, the smaller base of the cone being found at the face of each hoop which was, in the applications, nearest to the ends of the cast-iron cylinders, the same face of each hoop being placed outwards in each test.

The following statement exhibits the original and developed eccentricity of the hoops:

Eccentricity on interior diameters in inches.

	Hoop No. 9018, oil-tempered.	Hoop No. 9020, annealed.
	Inch.	*Inch.*
Original:		
Eccentricity, or maximum difference observed in any set of 4 diameters	0.003	0.002
Mean eccentricity, or greatest difference between the means of the measurements taken on each of the 4 series of diameters	0.0019	0.0013
Following the elastic test:		
Maximum eccentricity, as above	0.016	0.0185
Mean eccentricity, as above	0.015	0.0179
Following the strength test:		
Maximum eccentricity, as above	0.0355	0.0265
Mean eccentricity, as above	0.0343	0.0242

Plate *II* is intended to illustrate the mean eccentricity of the hoops in the *three stages*, viz: original, following elastic test, and following *strength test*, and also the mean permanent set for the last two stages.

The values used in the construction of the curves of eccentricity, the ordinates of which represent permanent set, are derived from Tables I, II, III, and IV, Appendix, by taking half the difference—that is, the radial difference—between the original grand mean diameter of each hoop and the mean of each of the four series of diameters measured at the different stages. The development of only half the circumference is shown, since the other half would be similar. Twice the difference between the greatest and least ordinates (measured from the horizontal "datum line") of each curve will be found to correspond with the "mean eccentricity" given in the tabular statement next preceding. The ordinates used for laying off the horizontal lines of "mean set" from the datum line are taken from the summaries of the tables named above, half the "grand means" therein given being used to lay off the radial set.

An examination of Plate II and the data from which it is constructed, shows that in the elastic test diameter No. 1, of the oil-tempered hoop, received the greatest permanent set, and diameter No. 3 the least; and this same relation held in the "set" following the strength test. On the other hand, in the elastic test of the annealed hoop, diameter No. 1 received the least set and diameter No. 3 the greatest, whilst this relation was reversed in the "set" following the strength test of this hoop.

Since an abnormally extended diameter would indicate weak places in the hoop at one or both of its extremities, and since the principal object of the test for strength was to develop whatever weak places might exist, it becomes important to examine the causes of this unequal permanent set. We conceive that it might be due to one of the following causes, or to two or more combined:

1. The original eccentricity of the hoops, that is to say, whether the diameter which is greatest before the application is also greatest after the test. This cause, however, could at most have a slight effect.

2. The original eccentricity of the exterior of the cylinders, since we might expect to find a maximum extension of the hoop over the maximum diameter of the cylinder.

3. The unequal cooling, by water, of any particular portion of the hoops after heating for the application.*

4. Weak places in the metal.

We may at once combine the first two causes. In the elastic test the greatest interior diameter of the oil-tempered hoop was applied over the least exterior diameter of the cylinder (we treat here only of the means of the series of diameters No. 1 and No. 3), and after the test this diameter of the hoop remained the greatest. But when in this test the greatest interior diameter of the annealed hoop was placed upon the least diameter of the cylinder, we find that after the test this diameter of the hoop was the least. In the strength test the greatest final diameters of both hoops were found to correspond to the greatest exterior diameters of the cylinder before the application. These results indicate that whilst the effect of these causes cannot be defined for the elastic test, yet in the strength test, where the hoops were excessively strained, it appears that the original eccentricity of the cylinder probably did influence the results.

In regard to the effect of unequal cooling. It so happened that in cooling the hoops in both tests, one extremity of diameter No. 1 received an occasional overflow of water from the bore of the cylinder. This began soon after the hoops were taken from the fire, and continued for some 45 minutes before the rest of the hoop was cooled with water. Hence, while the hoop was at its greatest heat, it may be said that this extremity of diameter No. 1 was a little more rapidly cooled than any other part of the hoop. On viewing the results one is tempted to ascribe a large influence to this cause, for in three cases out of four (two hoops and two tests) diameter No. 1 is abnormally extended. This view of the case, however, would indicate either that the unequal cooling of the metal had weakened it or else caused it to clamp the metal less forcibly than it would have done if left to cool more slowly, which latter is, it is believed, contrary to general opinion. A marked exception to the above must, however, be noted when we see that in the elastic test diameter No. 1 of the annealed hoop was the least extended of the four, and this case alone gives the effect that would have been anticipated from unequal cooling.

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* Unequal heating is omitted in this category, since there is every reason to believe that the hoops were heated equally throughout.

In the final examination of the hoops, made after the test for strength was finished, there could be discovered no evidences of flaws or cracks in the metal to indicate weak places. We know that after the final test diameter No. 1 of each hoop was the most extended, and thence conclude that the fibers adjacent to one or both of its extremities offered a diminished resistance to the stress. We conclude that this result was effected partly by the original eccentricity of the cast-iron test cylinders but to a slight degree; and that the effect of the unequal cooling was little, if any, for all told the amount of water that reached the hoop in the way described was not sufficient to reduce the temperature of that part of the hoop very considerably. Hence we must attribute the final shape of the hoop principally to unequal strength in the different parts of the hoops themselves. In any event the annealed hoop gives evidence of more uniform ultimate strength than the oil-tempered hoop, since its final curve of eccentricity (or permanent set) is the flattest of the two. This conclusion is likewise confirmed by the tensile test of the four 3-inch specimens which show the more uniform results for the ultimate tenacity of the annealed hoop.

SEC. 17. To illustrate the original and developed conicalness of the hoops, we may refer all the measurements of the 5 mean diameters, measured in sets of 4, to that one of them which was taken at 0.1 inch from the top of each hoop. Calling this diameter zero, we obtain the following differences:

Conicalness of hoops.

Mean diameters.	Distance from outside of hoops in place.				
	0.1	1.45	2.75	4.1	5.4
	Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*
Hoop No. 9018, oil-tempered:					
Original	0.	-0.000125	0.	+0.000125	+0.0015
Following elastic test	+0.00175	+0.0015	+0.00175	+0.002125	+0.004625
Following strength test	+0.044	+0.0475	+0.051125	+0.0545	+0.060375
Hoop No. 9020, annealed:					
Original	0.	—0.000875	—0.000375	+0.001125	+0.003375
Following elastic test	+0.0065	+0.00775	+0.010875	+0.0145	+0.018375
Following strength test	+0.05875	+0.060875	+0.06525	+0.07025	+0.0755

These results show—following the tests—an unbroken increase of set from the least, at the mean diameters taken as zero which were applied 0.25 inches from the ends of the cast-iron cylinders, to the greatest at the mean diameters near the opposite faces of the hoops which were applied about the middle length of the cylinders. The effects produced can only be explained by supposing that the cast iron near the ends of the cylinders offered a diminished resistance to the contractile forces of the hoops, and this although the hoops were set back 0.125 inches from the ends of the cylinders.

CONCLUSIONS.

The results attest the excellent quality of both hoops. They show that the oil-tempered hoop is much superior in elastic properties, not only that its elastic limit is very much higher, but also that its behavior under stresses approaching its elastic limit is relatively the more uniform, and, further, that its contractile force retains its relative superiority under stresses considerably above the elastic limit of the metal of both hoops.

The annealed hoop, however, was placed at a decided disadvantage in the commencement, when the shrinkage given in the elastic test was so great that the elastic limit of its metal was exceeded. It can be readily said of this hoop that nothing has been developed by these tests to show that hoops of similar quality to this would give other than excellent results if used in gun construction and applied with a shrinkage adapted to the elastic limit of the metal as determined by tensile tests of specimen bars taken from the hoops after their manufacture.

In relative behavior the annealed hoop evidenced a superiority over the oil-tempered hoop in one respect only, viz. that of greater uniformity in ultimate strength, as shown by its final shape; that is, it was less eccentric than the oil-tempered hoop after the removal of the cylinder in the final test for strength. Its superiority in the respect stated rests on the above fact, for although it came out of this final test with more extension than the oil tempered hoop, yet an examination of the records (see tabular statement, section 16) and of Plate II will show that the difference in eccentricity developed in the oil-tempered hoop by the two tests was relatively much greater than the same difference in the annealed, thus showing that the oil-tempered hoop was, in the final stage, *giving* the more unequally of the two. This does not conflict with the superiority of contractile force shown by the oil-tempered hoop, but it does show that this hoop even in its weakest parts is the stronger of the two, at least up to the point reached in these tests.

In conclusion, it may be stated that the results of these shrinkage tests confirm the results of the tensile tests at every point in which they can be compared.

APPENDIX.

RECORDS OF MEASUREMENTS PERTAINING TO THE TEST FOR ELASTICITY.

[Oil-tempered (Midvale) steel hoop, No. 9018; annealed (Midvale) steel hoop, No. 9020; cast-iron test-cylinder, No. 1.]

TABLE I.—*Oil-tempered (Midvale) steel hoop, No.* 9018.

Interior diameters of the hoop prepared for application.						Interior diameters of the hoop after removing the cylinder.					
Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.	Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.1	45.63	45.631	45.63	45.629	45.63	0.1	45.641	45.628	45.6255	45.6325	45.63175
1.45	45.6295	45.6315	45.6295	45.629	45.629876	1.45	45.64	45.6285	45.625	45.6325	45.6315
2.75	45.6305	45.6315	45.629	45.629	45.63	2.75	45.6395	45.629	45.626	45.6325	45.63175
4.1	45.6305	45.6305	45.6295	45.63	45.630125	4.1	45.6405	45.6285	45.6255	45.634	45.632125
5.4	45.6320	45.633	45.63	45.631	45.6315	5.4	45.644	45.63	45.628	45.6365	45.634625
Means	45.6305	45.6315	45.6296	45.6296	45.6303	Means	45.641	45.6288	45.626	45.6336	45.63235

SUMMARY.

	Mean interior diameters.					
	0.1 inch.	1.45 inches.	2.75 inches.	4.1 inches.	5.4 inches.	Grand means.
After removal	45.63175	45.6315	45.63175	45.632125	45.634625	45.63235
Before application	45.63	45.629875	45.63	45.630125	45.6315	45.63030
Difference equals permanent elongation	.00175	.001625	.00175	.002	.003125	.00205

TABLE II.—*Annealed (Midvale) steel hoop, No.* 9020.

Interior diameters of the hoop prepared for application.						Interior diameters of the hoop after removing the cylinder.					
Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameter.	Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches*	*Inches.*	*Inches.*	*Inches.*
0. 1	45. 629	45. 629	45. 629	45 6295	45. 629125	0. 1	45. 626	45. 6395	45. 6435	45. 6335	45. 635625
1. 45	45. 629	45. 6285	45. 6275	45. 628	45. 62825	1. 45	45. 627	45. 6405	45. 6445	45. 6355	45. 636875
2. 75	45. 63	45. 6285	45. 6280	45. 6285	45. 62875	2. 75	45. 6303	45. 6425	45. 6485	45. 6385	45. 64
4. 1	45. 6315	45. 6295	45. 6295	45. 6305	45. 63025	4. 1	45. 634	45. 6435	45. 6525	45. 6445	45. 643625
5. 4	45. 633	45. 6320	45. 6320	45. 633	45. 6325	5. 4	45. 6385	45. 6465	45 6565	45. 6485	45. 6475
Means	45. 6305	45. 6296	45. 6292	45. 6299	45. 629775	Means	45. 6312	45. 6425	45. 6491	45. 6401	45. 640725

SUMMARY.

	Mean interior diameters.					
	0. 1 inch.	1. 45 inches.	2. 75 inches.	4. 1 inches.	5. 4 inches.	Grand means.
After removal	45. 635625	45. 636875	45. 64	45. 643625	45. 6475	45. 640725
Before application	45. 629125	45. 62825	45. 62875	45. 6 025	45. 6325	45. 629775
Difference equals permanent elongation	. 0065	. 008625	. 01125	. 013375	. 015	. 01095

TABLE III.—*Cast-iron test-cylinder No. 1.*

BORE OF CYLINDER, INTERIOR DIAMETERS.

Before applying the hoops.						With the hoops applied.					
Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.	Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.25	18.4	18.405	18.4065	18.399	18.402625	0.25	18.386	18.3915	18.394	18.3885	18.39
1.25	18.396	18.396	18.401	18.396	18.39725	1.25	18.384	18.385	18.390	18.3845	18 385875
2.25	18.393	18.394	18.401	18.395	18.39575	2.25	18.3815	18.3815	18.388	18.384	18.38375
3.25					*18.399425	3.25	18.3825	18.3865	18.3885	18.386	18.385875
4.25	18.3975	18.404	18.402	18.3985	18.4005	4.25	18.385	18.386	18.3885	18.387	18.386625
6.25	18.398	18.402	18.404	18.4	18.401	6.25	18.3845	18.387	18.3895	18.387	18.387
8.25	18.402	18.403	18.405	18.402	18.403	8.25	18.387	18.390	18.390	18.390	18.38925
9.25	18.4	18.403	18.406	18.402	18.40275	9.25	18.387	18.387	18.391	18.390	18.38875
10.25	18.4	18.4035	18.40525	18.40425	18 40325	10.25	18.3865	18.3875	18.391	18.3905	18.388875
11.25	18.40175	18.405	18.40775	18.40575	18.4050625	11.25	18.387	18.389	18.393	18.3905	18.389875
11.875	18.40275	18.40625	18.4075	18.405	18.405375	11.875	18.3885	18.390	18.3925	18.3905	18.390375

EXTERIOR DIAMETERS OF CYLINDER (BEFORE APPLYING THE HOOPS).

0.25	45.717	45.7225	45.7205	45.7145	45.718625	45.7164625	Hoop No. 9020 (annealed) applied over this portion of the cylinder.
1.25	45.718	45.718	45.717	45.71	45.71575		
2.25	45.714	45.716	45.7155	45.71	45.713875		
3.25	No instruments available for measuring these diameters; a mean of all the *measured* diameters has therefore been taken for each *unmeasured* diameter.				45.71685		
4.25					45.71685		
5.25					45.71685		
7.25					45.71685	45.71723125	Hoop No. 9018 (oil-tempered) applied over this portion of the cylinder.
8.25					45.71685		
9.25	45.7185	45.721	45.719	45.713	45.717875		
10.25	45.718	45.7195	45.71575	45.71475	45.717		
11.25	45.71775	45.7205	45.71575	45.71275	45.7166875		
11.875	45.71875	45.72125	45.7175	45.715	45.718125		

Under hoop No. 9020, annealed.				Under hoop No. 9018, oil-tempered.			
Mean interior diameters.			Compression of the bore.	Mean interior diameters.			Compression of the bore.
Distance from top.	Before application of hoop.	With hoop applied.		Distance from top.	Before application of hoop.	With hoop applied.	
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0. 25	18. 402625	18. 39	0. 012625	6. 25	18. 401	18. 387	0. 014
1. 25	18. 397250	18. 385875	0. 011375	8. 25	18. 403	18. 38925	0. 01375
2. 25	18. 395750	18. 383750	0. 012	9. 25	18. 40275	18. 38875	0. 014
3. 25	*18. 399425	18. 385875	0. 01355	10. 25	18. 40325	18. 388875	0. 014375
4. 25	18. 400500	18. 386625	0. 013875	11. 25	18. 4050625	18. 389875	0. 0151875
6. 25	18. 401	18. 387	0. 014	11. 875	18. 405375	18. 390375	0. 015
Means	18. 399425	18. 386521	0. 012904	Means	18. 40340625	18. 389021	0. 0143853

* Not measured; an average used.

TABLE IIIa.—*Length of cast-iron test cylinder, No. 1.*

Before applying the hoops.						With the hoops applied.					
On circumference of circle.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean lengths.	On circumference of circle.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean lengths.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
*0.25	12.065	12.066	12.065	12.0685	12.065875	*0.25	12.0685	12.068	12.064	12.0705	12.0688125
	12.068	12.068	12.0635	12.063			12.0725	12.071	12.068	12.068	
*5.00	12.074	12.076	12.073	12.076	12.07375	*5.00	12.077	12.077	12.0705	12.079	12.076
	12.074	12.0745	12.0715	12.071			12.078	12.077	12.0745	12.075	
†0.25	12.080	12.082	12.080	12.080	12.080	†0.25	12.084	12.084	12.082	12.0845	12.0830625
	12.083	12.081	12.076	12.078			12.085	12.0845	12.081	12.0795	

* From bore. † From outside.

SUMMARY.

	Mean lengths on circumference of circles.			
	From bore		From outside.	Grand means.
	0.25 inch.	5 inches.	0.25 inch.	
With the hoops applied	12.0688125	12.076	12.0830625	12.0759583
Before applying the hoops	12.065875	12.07375	12.080	12.07321
Difference equals elongation of cylinder	0.0029375	0.00225	0.0030625	0.0027483

RECORD OF MEASUREMENTS PERTAINING TO THE TEST FOR STRENGTH.

[Oil-tempered (Midvale) steel hoop No. 9018; annealed (Midvale) steel hoop No. 9020; cast-iron test cylinder No. 2.]

TABLE IV.—*Oil-tempered (Midvale) steel hoop No.* 9018.

Interior diameters of the hoop before application.*						Interior diameters of the hoop after removing the cylinder.					
Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.	Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.1	45.641	45.628	45.6255	45.6325	45.63175	0.1	45.691	45.6715	45.657	45.6765	45.674
1.45	45.64	45.6285	45.625	45.6325	45.6315	1.45	45.6945	45.6745	45.6615	45.6795	45.6775
2.75	45.6395	45.629	45.626	45.6325	45.63175	2.75	45.699	45.6785	45.6635	45.6835	45.681125
4.1	45.6405	45.6285	45.6255	45.634	45.632125	4.1	45.7025	45.6805	45.6685	45.6865	45.6845
5.4	45.644	45.63	45.628	45.6365	45.634625	5.4	45.7085	45.687	45.6735	45.6925	45.690375
Means.....	45.641	45.6288	45.626	45.6336	45.63235	Means......	45.6991	45.6784	45.6648	45.6837	45.6815

* Same as after removing test cylinder No. 1.

SUMMARY.

	Mean interior diameters.					
	0.1 inch.	1.45 inches.	2.75 inches.	4.1 inches.	5.4 inches.	Grand means.
After removal	45.674	45.6775	45.681125	45.6845	45.690375	45.6815
Before application	45.63175	45.6315	45.63175	45.632125	45.634625	45.63235
Difference equals permanent elongation	.04225	.046	.049375	.052375	.05575	.04915

TABLE V.—*Annealed (Midvale) steel hoop No. 9020.*

Interior diameters of the hoop before application.*						Interior diameters of the hoop after removing the cylinder.					
Dsitance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.	Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.1	45.626	45.6395	45.6435	45.6335	45.635625	0.1	45.699	45.6865	45.677	45.6895	45.688
1.45	45.627	45.6405	45.6445	45.6355	45.636875	1.45	45.701	45.689	45.678	45.692	45.69
2.75	45.6305	45.6425	45.6485	45.6385	45.64	2.75	45.706	45.693	45.6815	45.697	45.694375
4.1	45.634	45.6435	45.6525	45.6445	45.643625	4.1	45.7125	45.6965	45.686	45.7025	45.699375
5.4	45.6385	45.6465	45.6565	45.6485	45.6475	5.4	45.717	45.7025	45.692	45.707	45.704625
Means	45.6312	45.6425	45.6491	45.6401	45.640725	Means	45.7071	45.6935	45.6829	45.6976	45.695275

SUMMARY.

	Mean interior diameters.					
	0.1 inch.	1.45 inches.	2.75 inches.	4.1 inches.	5.4 inches.	Grand means.
After removal	45.688	45.69	45.694375	45.699375	45.704625	45.695275
Before application	45.635625	45.636875	45.64	45.643625	45.6475	45.640725
Difference equals permanent elongation	.052375	.053125	.054375	.05575	.057125	.05455

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* Same as after removing test cylinder No. 1.

TABLE VI.—*Cast-iron test-cylinder No. 2.*

BORE OF CYLINDER—INTERIOR DIAMETERS.

Before applying the hoops.						With the hoops applied.					
Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.	Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.25	18.4	18.4	18.3975	18.3995	18.39925	0.25	18.388	18.3885	18.3825	18.385	18.386
1.25	18.3995	18.4	18.395	18.396	18.397625	1.25	18.3815	18.384	18.379	18.380	18.381125
2.25	18.4	18.3995	18.3965	18.396	18.398	2.25	18.381	18.3815	18.3785	18.378	18.37975
3.25	18.399	18.399	18.396	18.3965	18.397625	3.25	18.381	18.38	18.3785	18.3785	18.3795
4.25	18.397	18.398	18.395	18.3945	18.396125	4.25	18.379	18.379	18.376	18.376	18.3775
6.25	18.4005	18.398	18.397	18.397	18.398125	6.25	18.38	18.379	18.377	18.375	18.37775
8.25	18.3995	18.397	18.395	18.395	18.396625	8.25	18.377	18.3765	18.375	18.3745	18.37575
9.25	18.4	18.397	18.396	18.396	18.39725	9.25	18.3775	18.377	18.3745	18.3745	18.375875
10.25	18.3975	18.396	18.396	18.3965	18.3965	10.25	18.3765	18.376	18.374	18.374	18.375125
11.25	18.3965	18.3955	18.394	18.3935	18.394875	11.25	18.375	18.374	18.373	18.3735	18.373875
11.875	18.396	18.394	18.3925	18.393	18.393875	11.875	18.374	18.3725	18.3725	18.372	18.37275

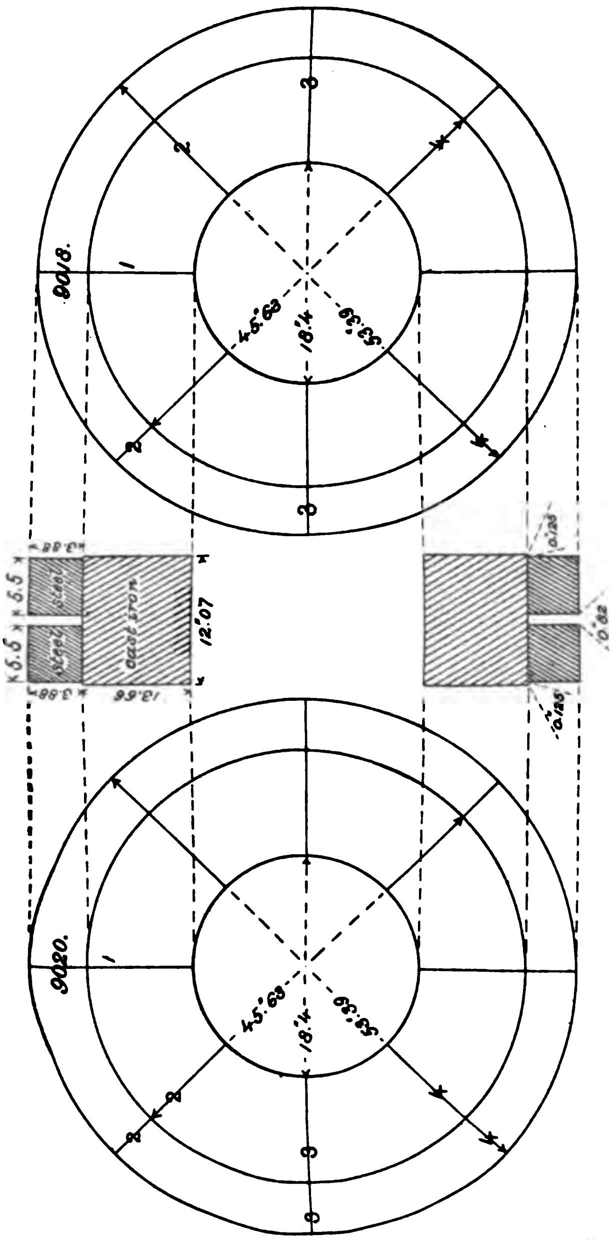
EXTERIOR DIAMETERS OF CYLINDER (BEFORE APPLYING THE HOOPS).

0.25	45.798	45.7965	45.7935	45.7985	45.796625	45.794196	Hoop No. 9020 (annealed) applied over this portion of the cylinder.
1.25	45.7955	45.792	45.789	45.7945	45.79245		
2.25	45.7945	45.79	45.7875	45.7925	45.791125		
3.25	45.796	45.793	45.789	45.7955	45.793375		
4.25	No instruments available for measuring these diameters. A mean of all the *measured* diameters has therefore been taken for each *unmeasured* diameter.				45.7958		
5.25					45.7958		
7.25					45.7958	45.797404	Hoop No. 9018 (oil tempered) applied over this portion of the cylinder.
8.25	45.8025	45.7965	45.796	45.798	45.79825		
9.25	45.802	45.7975	45.797	45.7995	45.799		
10.25	45.7995	45.7955	45.7965	45.798	45.797375		
11.25	45.801	45.796	45.7955	45.796	45.797125		
11.875	45.8005	45.7956	45.7945	45.797	45.796875		

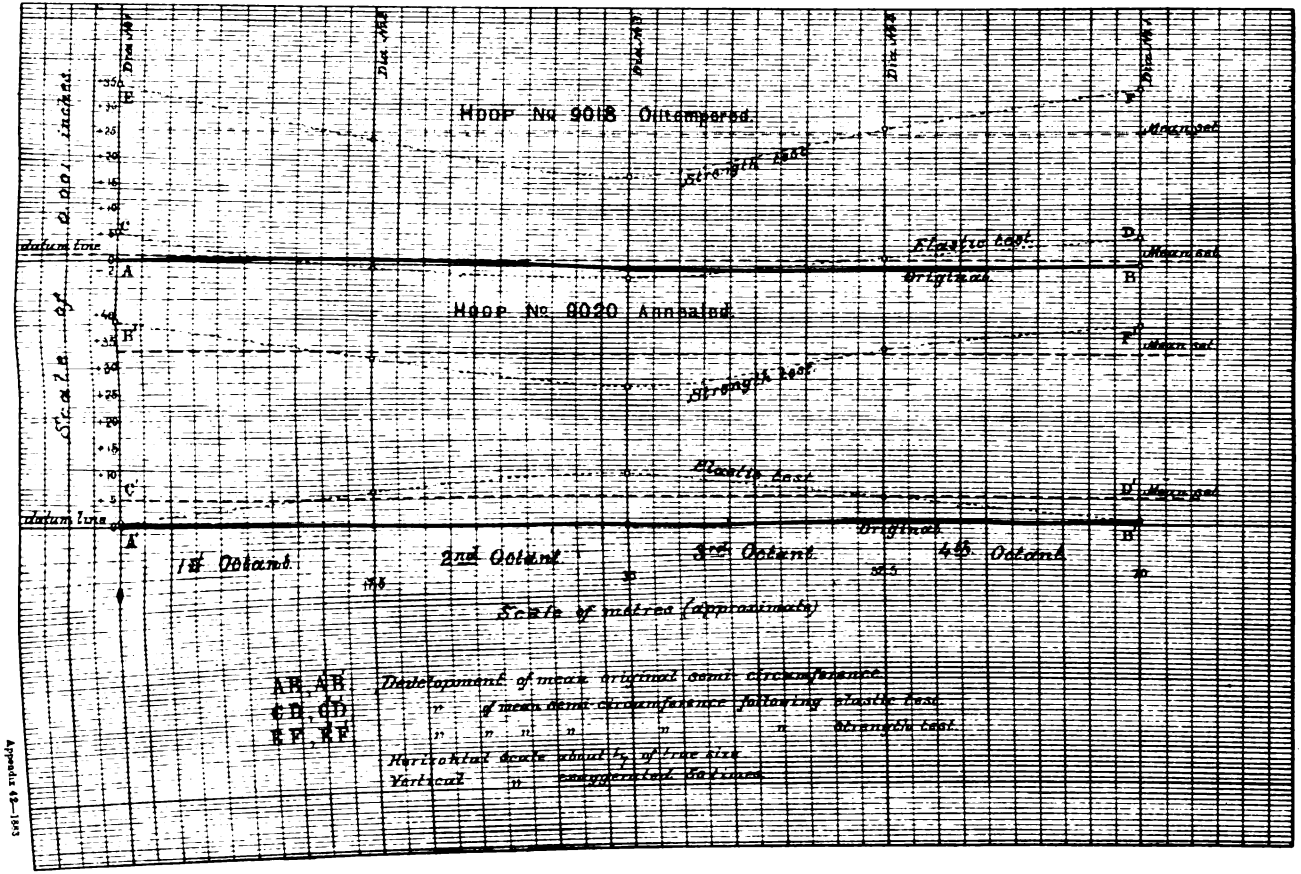
SUMMARY—COMPRESSION OF THE BORE.

Under hoop No. 9020, annealed.				Under hoop No. 9018, oil-tempered.			
Mean interior diameters.			Compression of the bore.	Mean interior diameters.			Compression of the bore.
Distance from top.	Before application of hoop.	With hoop applied.		Distance from top.	Before application of hoop.	With hoop applied.	
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0. 25	18. 39925	18. 386	0. 01325	6. 25	18. 398125	18. 37775	0. 020375
1. 25	18. 397625	18. 381125	0. 0165	8. 25	18. 396625	18. 37575	0. 020875
2. 25	18. 398	18. 37975	0. 01825	9. 25	18. 39725	18. 375875	0. 021375
3. 25	18. 397625	18. 3795	0. 018125	10. 25	18. 3965	18. 375125	0. 021375
4. 25	18. 396125	18. 3775	0. 018625	11. 25	18. 394875	18. 373875	0. 021
6. 25	18. 398125	18. 37775	0. 020875	11. 875	18. 393875	18. 37275	0. 021125
Means	18. 397792	18. 380271	0. 017521	Means	18. 39621	18. 3751875	0. 021021

SECTIONAL AND END VIEWS SHOWING HOOPS APPLIED TO CYLINDERS.



ECCENTRICITY AND PERMANENT SET ON INTERIOR RADII OF HOOPS, IN INCHES.



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